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INTRODUCTION TO CRITICAL PATH SCHEDULING.
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INFORMATION IS PRESENTED FOR STUDENT USE IN LEARNING PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT), A PROJECT MANAGEMENT SYSTEM USED TO PLAN, CONTROL, AND EVALUATE PROJECTS. THE MATERIAL WAS PREPARED IN THE IBM DISTRICT 15 EDUCATIONAL CENTER TO BE USED IN VOCATIONAL CLASSES. THE TECHNIQUE WAS DEVELOPED DURING 1958 BY THE NAVY FOR APPLYING STATISTICAL AND MATHEMATICAL TECHNIQUES TO PROJECT MANAGEMENT FOR A LARGE WEAPONS SYSTEM, THE POLARIS MISSILE AND SUBMARINE. THE OBJECTIVES OF THE TEXT ARE TO (1) INTRODUCE THE STUDENT TO PERT CONCEPTS, (2) PROVIDE PROBLEMS AND EXAMPLES THAT WILL SOLIDIFY HIS LEARNING, (3) DEMONSTRATE HOW A COMPUTER IS USED WITH PERT, AND (4) ASSEMBLE INFORMATION ABOUT THE ENTIRE PERT CYCLE IN ONE SOURCE. UPON COMPLETION OF THE COURSE THE STUDENT SHOULD BE ABLE TO SELECT A PROJECT WHERE PERT MAY BE BENEFICIAL, USE PERT IN PLANNING AND SCHEDULING THE PROJECT, APPLY COSTS TO A PERT PROJECT, AND PROVIDE MANAGEMENT WITH USEFUL INFORMATION DISPLAYS. SECTIONS OF THE TEXT COVER--(1) GENERAL INFORMATION, (2) PROJECT PLANNING, (3) PROJECT TIME SCHEDULING, (4) RESOURCE SCHEDULING, AND (5) PROJECT CONTROL. DIAGRAMS, GLOSSARIES, TABLES, AND REFERENCES ARE INCLUDED. (FP)

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Introduction to

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INTRODUCTION TO

CRITICAL PATH SCHEDULING

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1964

A STUDENT TEXT FOR A PROJECT MANAGEMENT SYSTEM

.....P.....PROGRAM
.....E.....EVALUATION
.....R.....REVIEW
.....T.....TECHNIQUE

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OBJECTIVES OF PERT COURSE
****

THE OBJECTIVES OF THIS COURSE ARE

- TO INTRODUCE THE STUDENT TO PERT CONCEPTS.
- TO PROVIDE PROBLEMS AND EXAMPLES THAT WILL SOLIDIFY HIS LEARNING.
- TO DEMONSTRATE HOW A COMPUTER IS USED WITH PERT.
- TO ASSEMBLE IN ONE SOURCE INFORMATION ABOUT THE ENTIRE PERT CYCLE.

UPON COMPLETION OF THE COURSE THE STUDENT WILL BE ABLE TO

- SELECT A PROJECT WHERE PERT MAY BE BENEFICIAL.
- PLAN THE PROJECT USING PERT.
- SCHEDULE THE PROJECT USING PERT.
- APPLY COSTS TO A PERT PROJECT.
- PROVIDE MANAGEMENT WITH USEFUL INFORMATION DISPLAYS.

INTRODUCTION TO PERT
****

ONE OF THE MOST SIGNIFICANT ADVANCES IN MANAGEMENT METHODS DEVELOPED RECENTLY HAS BEEN PERT, PROGRAM EVALUATION AND REVIEW TECHNIQUE. THE PERT TECHNIQUE WAS DEVELOPED DURING 1958 AT THE NAVY SPECIAL PROJECTS OFFICE UNDER ADMIRAL W.F. RABORN FOR THE APPLICATION OF STATISTICAL AND MATHEMATICAL TECHNIQUES TO PROJECT MANAGEMENT FOR A LARGE WEAPONS SYSTEM, THE POLARIS MISSLE AND SUBMARINE. THE TECHNIQUE WAS INSTITUTED TO AID IN PLANNING AND CONTROLLING THREE MAJOR FACTORS OF LARGE SYSTEMS DEVELOPMENT.....TIME, COST AND TECHNICAL PERFORMANCE. ALTHOUGH PERT WAS THE BASIC FRAMEWORK OF MONITORING AND CONTROL, ITS INITIAL USE WAS IN THE EVALUATION OF SCHEDULES, THE TIME ASPECT.

PERT BASED SYSTEMS ARE SOUND, DYNAMIC MANAGEMENT TECHNIQUES WHICH HAVE BEEN USED IN A VARIETY OF INDUSTRIES. USERS HAVE INCLUDED THE MILITARY, AEROSPACE INDUSTRIES, AIRFRAME FABRICATORS, PETROLEUM AND CHEMICAL INDUSTRIES, MANUFACTURING PLANTS, ENGINEERING FIRMS, AND OTHERS. THESE PERT BASED SYSTEMS ARE NOT THE ULTIMATE, BUT THEY AND THEIR REFINEMENTS PROVIDE THE NECESSARY INFORMATION FOR BETTER PROJECT MANAGEMENT.

THE TYPES OF PROJECTS FOR WHICH THE PERT SYSTEM CAN BE USED ARE AS VARIED AS ANY THAT EXIST IN INDUSTRY. IN GENERAL, PERT CAN BE USED ON ANY PROJECT MADE UP OF GROUPS OF ACTIVITIES WHICH CAN BE SEQUENCED INTO A COMBINATION OF PARALLEL AND SERIAL CHAINS. SUCH A SEQUENCED SET OF ACTIVITIES IS THE PERT NETWORK. THE BASIC OBJECTIVE OF THE PERT SYSTEM IS TO ASSOCIATE THE VARIOUS ACTIVITIES TO BE PERFORMED WITHIN A PROJECT WITH THEIR RELATED SCHEDULES, MANPOWER REQUIREMENTS, AND COST INFORMATION.

PERT IS A DYNAMIC AND RESPONSIVE PROJECT MANAGEMENT SYSTEM. IT IS USED TO PLAN, CONTROL, AND EVALUATE PROJECTS. PERT IS A DISCIPLINE WHICH REQUIRES A PROJECT TO BE CAREFULLY ORGANIZED AND DESCRIBED WITH CONCISE TERMS. THIS METHOD OF PROJECT MANAGEMENT SELLS ITSELF TO ALL LEVELS OF MANAGEMENT AND OPERATING PERSONNEL. PERT ENABLES MANAGEMENT TO TEST ALTERNATIVES AND DETERMINE THEIR CONSEQUENCES BEFORE A DECISION IS MADE. PERT PROVIDES REALISTIC AND EASILY UNDERSTOOD OPERATING PLANS. THESE PLANS ARE BASED ON THE ACTUAL CAPABILITIES OF AN ORGANIZATION. PERT MAKES MAXIMUM UTILIZATION OF ALL AVAILABLE PLANNING DATA THAT MAY HAVE BEEN PREPARED IN CONNECTION WITH A PROJECT. PERT PERMITS A HIGHLY OBJECTIVE ANALYSIS OF THE STRONG AND WEAK AREAS OF A PROJECT. THE SIMPLICITY OF PERT RESULTS IN A VERY SHORT LEARNING CYCLE. THIS PERMITS IMMEDIATE IMPLEMENTATION OF THE SYSTEM. MAXIMUM BENEFITS ARE REALIZED IN A SHORT PERIOD OF TIME WITH A SMALL EXPENDITURE OF EFFORT.

THE PAST DECADE HAS WITNESSED A STEADY GROWTH IN THE APPLICATION OF ANALYTICAL AIDS TO PLANNING. IN THIS AREA THE DEVELOPMENT AND APPLICATION OF PERT AND PERT-LIKE SYSTEMS IN PROGRAM CONTROL HAS BEEN PERHAPS THE MOST WIDELY DISCUSSED. THE TERM PERT-LIKE IS USED AS AN IDENTIFIER AND FOR PURPOSES OF ECONOMY. MANY DIFFERENT NAMES HAVE BEEN APPLIED TO OR COINED TO DESCRIBE THE NETWORK APPROACH AND CHANGES TO IT. THIS JUNGLE OF TERMINOLOGY HAS BEEN CONFUSING TO MANAGEMENT. FOR THIS REASON, THE TERM PERT WILL BE USED AS A GENERAL IDENTIFIER.

VALUES OF PERT

****

PLANNING VALUES.....

- ARROW NETWORK CAUSES EVERYONE TO PLAN
- MANAGEMENT RESPONSIBILITIES ARE ESTABLISHED
- AN UNDERSTANDING OF INTERRELATIONSHIP OF ACTIVITIES IS GAINED
- ASSIGNMENT OF RESPONSIBILITES IS CLARIFIED
- A BASIS FOR EVALUATION OF THE PLAN IS GAINED
- MANAGEMENT CAN EXAMINE ALTERNATIVE PLANS
- MANAGEMENT CAN PLAN ONE OF A KIND PROGRAMS
- MANAGEMENT CAN PLAN PROGRAMS WHERE NO STANDARD COST AND TIME DATA ARE AVAILABLE
- A PROBABILITY OF SUCCESSFULLY MEETING DEADLINES IS REACHED

CONTROL VALUES.....

- PROGRESS REPORTING IS DYNAMIC RATHER THAN HISTORICAL
- PERT ALLOWS ANTICIPATORY MANAGEMENT ACTION AGAINST TROUBLE LIKELY TO APPEAR
- ABILITY TO TRADE OFF RESOURCES
- ABILITY TO SIMULATE PROGRAMS OR DECISIONS ON PAPER OR IN A COMPUTER INSTEAD OF TAMPERING WITH EXPENSIVE OPERATIONS
- MANAGEMENT CAN CONCENTRATE ON CONTROLLING CRITICAL ACTIVITIES RATHER THAN THE ENTIRE PROJECT
- A LARGE AMOUNT OF DATA IS PRESENTED AND SUMMARIZED BY PERT IN AN ORDERLY FASHION

SOURCES...REFERENCES 1 AND 2

TYPICAL USERS OF PERT
****

DEERE AND COMPANY

USE........PRODUCT DEVELOPMENT IN OTTUMWA WORKS

RESULTS....ESTIMATED TIME REDUCTION 28 PERCENT. NOW APPLIED TO
....ALL PROJECTS OF MORE THAN 200 MANHOURS.

DUPONT

USE........SHUTDOWN MAINTENANCE OF LOUISVILLE PLANT

RESULTS....REDUCED SHUTDOWN TIME BY 37 PERCENT. GAINED MORE THAN
....ONE MILLION POUNDS OF PRODUCTION.

INTERNATIONAL MINERALS AND CHEMICAL

USE........MAINTENANCE OF MINE HOIST REQUIRING SHUTDOWN OF MINE

RESULTS....27 PERCENT TIME REDUCTION. $100,000 SAVED.

CATALYTIC CONSTRUCTION COMPANY

USE........47 CONSTRUCTION PROJECTS

RESULTS....AVERAGE TIME REDUCTION FOR PROJECTS 22 PERCENT.
....EXPEDITING COSTS REDUCED AVERAGE OF 15 PERCENT

SUN MAID RAISIN GROWERS

USE........CONSTRUCTION OF PLANT PROPERLY TIMED TO GROWING SEASON

RESULTS....TIME REDUCTION OF 25 PERCENT.
....ESTIMATED SAVINGS OF $1,000,000

SOURCE...REFERENCE 1

APPLICATION AREAS OF PERT

THE FOLLOWING APPLICATION AREAS UTILIZE PERT OR ARE BEING CONSIDERED BY COMPANY MANAGEMENT

- SECURITIES ISSUES
- LONG RANGE PLANNING
- MARKETING PROGRAMS
- MERGERS OR ACQUISITION PROGRAMS
- INTRODUCTION OF NEW PRODUCTS
- ADVERTISING PROGRAMS
- STAFFING OF PLANTS
- INSTALLING OTHER MANAGEMENT CONTROL SYSTEMS
- INSTALLING ORGANIZATION PLANS
- BOOK PUBLICATION
- PRECRISIS PLANNING
- RESEARCH AND DEVELOPMENT
- CONSTRUCTION PROGRAMS
- PROGRAMMING OF COMPUTERS
- PREPARATION OF BIDS AND PROPOSALS
- MAINTENANCE PLANNING
- INSTALLATION OF COMPUTER SYSTEMS
- DISTRIBUTION PLANNING
- COST REDUCTION PROGRAMS
- SCHEDULING OF PAPERWORK
- OTHERS AD INFINITUM

SOURCE...REFERENCE 1

OBJECTIVES OF PERT
****

THE PERT SYSTEM AIMS TO PRESENT MEANINGFUL INFORMATION FOR PLANNING AND CONTROLLING PROJECTS. ONE OF THE PRIMARY BENEFITS IS A DEFINITE PLAN OF ACTION IN ATTACKING THE PROBLEM ONCE THE OBJECTIVES OF MANAGEMENT HAVE BEEN STATED. ANOTHER BENEFIT IS THE DISCIPLINE OF THINKING THE JOB THROUGH AT EACH LEVEL OF MANAGEMENT.

TO CARRY OUT THESE OBJECTIVES, THE SEQUENCED ACTIVITIES ARE GROUPED INTO A NETWORK. THIS NETWORK IS A PLAN OF ACTION. IT IS A REALISTIC AND UNDERSTANDABLE REPRESENTATION OF THE PROJECT AND PROVIDES THE FRAMEWORK OF THE SYSTEM. THE ELEMENTS OF PLANNING INFORMATION, COST ESTIMATES, ESTIMATED COMPLETION DATES, MANPOWER REQUIREMENTS, ARE THEN RELATED TO THE ELEMENTS OF THE NETWORK. THE PERT SYSTEM USES THIS INFORMATION IN PREPARING REPORTS FOR INTEGRATING THE PLAN OF ACTION AND ESTABLISHING SCHEDULES, BUDGETS AND MANPOWER ASSIGNMENTS.

WHEN THE SYSTEM IS IMPLEMENTED ON A PROJECT, THE ACTUAL OUTLAYS OF TIME, LABOR AND FUNDS ARE CORRELATED AGAINST THE PLAN, AND THIS INTEGRATED INFORMATION IS PRESENTED TO MANAGEMENT FOR REVIEW. FOR EXAMPLE, TIME, COST AND MANPOWER SUMMARIES CAN BE GIVEN FOR /1/ THE PROJECT THUS FAR, /2/ OUTLOOK AND ESTIMATES AND /3/ THE PLAN VERSUS ACTUALS.

FOR THE EVALUATION OF THIS INFORMATION, THE SYSTEM PROVIDES REPORTS WHICH MONITOR THE PLANNED PROGRAM AND PINPOINT THOSE AREAS WHICH MAY REQUIRE REMEDIAL ACTION. MANAGEMENT DECISIONS AND ACTIONS CAN BE MADE TO BRING ACTUAL PROGRESS CLOSER TO THE APPROVED PLAN OF ACTION.

SELECTION OF A PERT APPLICATION

THE APPLICATIONS OF PERT ARE INCREASING RAPIDLY AS PEOPLE BECOME FAMILIAR WITH THE TECHNIQUE. THE SIMPLICITY OF THE PERT CONCEPT IS RESPONSIBLE FOR ITS EXPANDED USE IN INDUSTRY. PERT USERS HAVE FOUND THE FOLLOWING CRITERIA HELPFUL IN SELECTING A PROJECT FOR PERT USE

- PROJECTS THAT INVOLVE SEVERAL PEOPLE, DEPARTMENTS, OR FUNCTIONS
- PROJECTS THAT HAVE A CRITICAL COMPLETION DATE
- PROJECTS THAT REQUIRE COSTLY RESOURCES
- PLANS THAT MUST BE TESTED BEFORE IMPLEMENTATION
- PROJECTS THAT ARE IN A CONSTANT STATE OF CHANGE
- PROJECTS THAT REQUIRE CONSIDERABLE COORDINATION AMONG THE FUNCTIONS THAT ARE CONTRIBUTORS TO THE PROJECT
- PROJECTS THAT MUST BE CONSTANTLY REVIEWED TO DETERMINE THE EFFECTS OF ACTUAL PERFORMANCE
- PROJECTS THAT INVOLVE A NUMBER OF INTERDEPENDENT EVENTS

THE ABOVE ITEMS COMPRISE ONLY A PARTIAL LIST OF CRITERIA WHICH THE PROSPECTIVE PERT USER MAY WISH TO CONSIDER. IT IS RECOMMENDED THAT INITIALLY A PROJECT OF RATHER SHORT DURATION AND NOT EXTREMELY COMPLICATED BE SELECTED. A FAMILIARITY WITH THE TECHNIQUE WILL OPEN NEW AREAS OF PROFITABLE APPLICATION FOR PERT.

KEY WORDS IN PROJECT SELECTION ARE

- COSTLY
- LENGTHY
- URGENT
- COMPLEX
- DYNAMIC

SOURCE...REFERENCE 8

PERT CYCLE
****

THE ILLUSTRATION SHOWN BY FIGURE A0 DEPICTS THE CYCLE THROUGH WHICH PERT SUPPLIES A CONTINUOUS STREAM OF TIMELY INFORMATION REQUIRED FOR EFFECTIVE PROGRAM EVALUATION.

THE CYCLE BEGINS WITH COMPUTER INPUTS FROM THE GROUP OR AGENCY CHARGED WITH MEETING A MAJOR END OBJECTIVE. THE OUTPUT REPORTS REQUIRE ANALYSIS. NECESSARY CHANGES OR CORRECTIONS ARE SUBMITTED FOR FURTHER REVISION AND REDISTRIBUTION.

PERIODIC REQUESTS FOR ADDITIONAL DATA WILL FOCUS ATTENTION ON RELATIVELY CRITICAL PATHS AND PERMIT THE AUDIT OF A FEW SPECIFIED EVENTS. RE-ESTIMATES MAY BE REQUESTED FOR THOSE TIMES THAT LIE ALONG THE CRITICAL PATHS. THIS SERVES TWO PURPOSES /1/ EMPHASIS IS PLACED ON TIGHT AREAS, AND /2/ ESTIMATES IN THESE AREAS ARE MARKED FOR CRITICAL ANALYSIS IN AN EFFORT TO PRODUCE MORE ACCURATE DATA.

AUDITING IMPROVES THE ACCURACY OF THE FLOW CHART BECAUSE ESTIMATES ARE REQUESTED FOR A SMALL GROUP OF SELECTED ACTIVITIES WHICH DIFFER FROM MONTH TO MONTH. ALL EVENTS ON THE CHART WILL BE COVERED AT ONE TIME OR ANOTHER.

SOURCE...REFERENCE 5

PLANNING THE NETWORK

****

PERT IS AN EXCELLENT TOOL FOR PLANNING. IT REQUIRES THE USER TO LOGICALLY EXAMINE THE PROJECT AND FORCES PLANNING OF ALL PORTIONS OF A JOB. OF COURSE, PLANNING HAS BEEN ACCOMPLISHED FOR MANY YEARS BY MEANS OF GANTT CHARTS. IN GANTT CHARTING USUALLY NO INTERCONNECTION OR DEPENDENCY BETWEEN ACTIVITIES ARE SHOWN. IN RESEARCH AND DEVELOPMENT PROGRAMS MANY PROJECTS MUST BE PERFORMED CONCURRENTLY AND COORDINATED PROPERLY. PERT OFFERS SIGNIFICANT IMPROVEMENT IN THESE AND OTHER SIMILIAR TYPE PROJECTS OVER EXISTING TECHNIQUES. FIGURE A18 SHOWS A TYPICAL GANTT CHART.

UNDER A PERT SYSTEM, A PROJECT IS FIRST PLANNED, THEN SCHEDULED USING TIME AND COST AND RESOURCES, AND THEN CONTROLLED. IT IS QUITE DIFFICULT FOR A MANAGER TO CONTROL UNLESS AN ACCEPTABLE PLAN HAS BEEN CREATED. DECISIONS SHOULD BE THE RESULTS OF PLANS AND POLICIES THAT HAVE BEEN DEVELOPED TO MEET OBJECTIVES AND SHOULD THEN BE RELATED TO CONTROL INFORMATION WHICH SHOWS ACCOMPLISHMENTS VERSUS PLAN.

THE TOOL USED FOR PLANNING IN PERT IS THE ARROW DIAGRAM. THIS DIAGRAM IS AN OUTLINE OF THE ACTIVITIES THAT MUST BE ACCOMPLISHED AND OF THE EVENTS THAT MUST OCCUR BEFORE AN OBJECTIVE IS REACHED. IT PROVIDES A SIMPLE, CLEAR, AND PRECISE DESCRIPTION OF THE PROJECT BEING UNDERTAKEN. THE DIAGRAM ALSO SERVES AS A TOOL FOR COMMUNICATION. USUALLY PEOPLE INVOLVED IN A PROJECT BELIEVE THAT THEIR PORTION IS THE ENTIRE PROJECT. IN REALITY, THEY ARE USUALLY PLANNING ONLY A PORTION OF THE PROJECT AND THE ARROW DIAGRAM ALLOWS THEM TO DETERMINE HOW THEY INTERFACE WITH OTHER DEPARTMENTS.

ONLY AFTER ALL AFFECTED DEPARTMENTS ARE CONVINCED THAT THE ARROW DIAGRAM REPRESENTS A WORKABLE PLAN SHOULD THE PROJECT BE SCHEDULED. AT THIS POINT ALL ACTIONS SHOULD HAVE BEEN EVALUATED TO DETERMINE WHETHER THEY ARE NECESSARY AND WHY THEY ARE NECESSARY. ALL SIGNIFICANT ACTIVITIES SHOULD HAVE BEEN DETERMINED AND THEIR RELATIONSHIPS DEFINED. MANAGEMENT SHOULD NOW BE ABLE TO EVALUATE THE PLAN AS TO COMPANY POLICIES AND LIMITS. BY CONSULTATION WITH THE PLANNER, A SUPERIOR RESULT SHOULD BE OBTAINED OVER USING EXISTING TECHNIQUES.

IN ORDER TO BEGIN ARROW DIAGRAMMING A FEW DEFINITIONS ARE REQUIRED.

DEFINITIONS

ACTIVITY
....
ONE TASK TO BE COMPLETED AS PART OF A PROJECT. AN ACTIVITY TAKES TIME AND CAUSES MONEY TO BE SPENT IN MANPOWER AND/OR MATERIALS.

EVENT
.....
A SPECIFIC ACCOMPLISHMENT DURING A PROJECT. AN EVENT SIGNIFIES THE START OR COMPLETION OF ONE OR MORE ACTIVITIES. IT THUS REPRESENTS A MILESTONE IN PROJECT PROGRESS. NO TIME OR COST IS ASSOCIATED WITH AN EVENT. IT IS SIMPLY A CONVENIENT WAY TO SEPARATE ACTIVITIES. EVENTS ARE NORMALLY REPRESENTED BY CIRCLES OR NODES AND EACH IS GIVEN A UNIQUE NUMBER.

ARROW DIAGRAM
....
A PICTORAL REPRESENTATION OF THE SEQUENCE OF ACTIVITIES WHICH MAKE UP PROJECT. EACH ACTIVITY IS REPRESENTED BY AN ARROW WHOSE TAIL IS CONNECTED TO THE ACTIVITY IMMEDIATELY PRECEDING IT, AND WHOSE HEAD IS CONNECTED TO THE ACTIVITY IMMEDIATELY FOLLOWING IT.

. . . ALL INTERDEPENDENCIES ARE SHOWN BY THE JUNCTIONS OF ARROWS.

. . . A SET OF RULES FOR CONSTRUCTING THE ARROW DIAGRAM HAS BEEN ESTABLISHED.

DUMMY ACTIVITY
....
AN ACTIVITY WITH ZERO DURATION SOMETIMES USED IN A NETWORK IN ORDER TO PROVIDE A UNIQUE PAIR OF NODES FOR EACH ACTIVITY.

JOB
...
ANOTHER NAME FOR ACTIVITY

NETWORK
....
ANOTHER NAME FOR ARROW DIAGRAM.

NODE
....
A REPRESENTATION OF AN EVENT BY A NUMBERED POINT

THE FOLLOWING SECTIONS REFER TO APPENDIX FIGURES THAT YOU SHOULD REFER TO AS YOU ARE STUDYING THE MATERIAL.

RULES FOR ARROW DIAGRAMMING

••••••••••••••••••••••••••

1. EACH ACTIVITY IS REPRESENTED BY ONE ARROW. FIGURE A1.

2. EACH ARROW MUST BEGIN AT SOME EVENT AND TERMINATE AT ANOTHER EVENT.

3. EACH EVENT OTHER THAN THE FIRST AND LAST EVENTS OF THE NETWORK MUST INITIATE AT LEAST ONE ACTIVITY AND TERMINATE AT LEAST ONE ACTIVITY. FIGURE A2.

4. THE PROJECT MUST BEGIN AND END WITH SINGLE EVENTS. THAT IS, THERE CANNOT BE TWO STARTING OR TWO ENDING EVENTS.

5. NO TWO OR MORE ACTIVITIES CAN BEGIN AND END WITH THE SAME TWO EVENTS. WHERE THIS OCCURS NATURALLY, ONE OR MORE DUMMY ACTIVITIES AND/OR DUMMY EVENTS MUST BE ADDED TO THE NETWORK. FIGURE A3. THUS, EACH ACTIVITY MAY HAVE A UNIQUE PAIR OF EVENTS AS ITS PREDECESSOR AND SUCCESSOR.

6. NO SET OF ACTIVITIES CAN CREATE A LOOP OR CYCLE. FIGURE A4.

RELATIONS BETWEEN JOBS IN THE DIAGRAM

•••••••••••••••••••••••••••••••••••

CONSIDER ANY ACTIVITY AND THE TWO NODES ASSOCIATED WITH IT. THERE MUST BE AT LEAST ONE ACTIVITY FOLLOWING AND AT LEAST ONE ACTIVITY PRECEDING EVERY ACTIVITY EXCEPT THE FIRST AND THE LAST.

CONSIDER A NODE, AND THE JOBS ENTERING AND LEAVING IT. IN FIGURE A5 THE RELATIONS BETWEEN ACTIVITES IS AS FOLLOWS

ACTIVITY	IS FOLLOWED BY	IS PRECEDED BY
A	D AND E	- - -
B	D AND E	- - -
C	D AND E	- - -
D	- - -	A, B AND C
E	- - -	A, B AND C

THE DIAGRAM FURTHER RESTRICTS RELATIONS. ACTIVITY D CANNOT BE STARTED UNTIL ACTIVITIES A, B AND C ARE COMPLETED AND ONCE THEY ARE COMPLETED NOTHING ELSE PREVENTS ACTIVITY D FROM PROCEEDING, ETC.

MULTIPLE VS SINGLE DEPENDENCIES

WHERE A NUMBER OF ACTIVITES ENTER AND EXIT FROM A COMMON NODE BUT ONE OR MORE ACTIVITIES NEED ONLY BE PRECEDED BY SOME OF THE ENTERING ACTIVITIES THESE ACTIVITIES ARE SEPARATED BY A DUMMY ACTIVITY. IF WE WANT TO EXPRESS THE CONDITIONS IN FIGURE A6 AND THE DIAGRAM IN FIGURE A7 IS USED, A FALSE RESTRICTION IS PLACED ON ACTIVITY C. FIGURE A8 IS A VALID DIAGRAM.

POINTS TO CONSIDER IN DETERMINING THE NETWORK

1. WHAT PRECEDES EACH ACTIVITY.

2. WHAT FOLLOWS EACH ACTIVITY.

3. WHAT OTHER ACTIVITIES OCCUR SIMULTANEOUSLY.

ONE WAY TO START IS BY DEVELOPING A TABLE IN WHICH EACH ACTIVITY APPEARS. THE TABLE SHOULD INCLUDE FOR EACH ACTIVITY A DELINEATION OF ALL OTHER ACTIVITIES WHICH IMMEDIATELY PRECEDE IT AND ALL THOSE WHICH IMMEDIATELY FOLLOW IT.

IDENTIFICATION	ACTIVITY	PREDECESSORS	SUCESSORS
A	RECEIVE ORDER FOR CAR	-	B, C, D
B	INSTALL OPTIONAL EQUIPMENT	A	F
C	SERVICE FOR DELIVERY	A	F
D	SET UP FINANCING	A	F
E	REGISTER VEHICLE	A	F
F	DELIVER TO CUSTOMER	B, C, D, E	-

USUALLY A NETWORK IS CREATED IN THIS MANNER

1. DEFINE THE FINAL OBJECTIVE EVENT.
2. DEFINE ALL SIGNIFICANT EVENTS THAT IMMEDIATELY PRECEDE THE END OBJECTIVE .
3. REPEAT STEP 2 FOR ALL EVENTS CREATED.

THE REASON FOR WORKING FROM THE END EVENT TOWARDS THE FRONT IS THAT IT IS EASIER TO VISUALIZE AND TO ASSURE THAT NOTHIGN SIGNIFICANT IN THE WHOLE PLAN IS LEFT OUT.

SOURCE...REFERENCE 9

THE FIRST ATTEMPT AT DIAGRAMMING IS OFTEN SIMPLIFIED BY USING DUMMIES GENEROUSLY. A SECOND DIAGRAM CAN THEN BE MADE, ELIMINATING UNNECESSARY DUMMIES. FIGURE A9

EACH ACTIVITY INCLUDING DUMMIES IS IDENTIFIED BY THE TWO EVENTS IT CONNECTS. IF THESE EVENTS ARE GIVEN NUMERIC IDENTIFICATION, THE ACTIVITY IS IDENTIFIED AS AIJ. THE EVENT AT THE TAIL OF THE ACTIVITY IS I, AND THAT AT THE HEAD IS J.

NODE NUMBERING

••••••••••••••

EACH NODE MUST HAVE A UNIQUE NUMBER WHICH MAY BE ARBITRARILY ASSIGNED. SOME CRITICAL PATH PROGRAMS REQUIRE THAT THE NODAL NUMBER AT THE TAIL OF EVERY ARROW BE LESS THAN THAT AT ITS HEAD. SOME ADDITIONALLY RESTRICT THAT THE NODES BE NUMBERED CONSECUTIVELY 1 TO N. PROGRAMS EXIST TO TAKE ANY ARBITRARY SET OF NODE NUMBERS AND TRANSPOSE THEM INTO A NUMBERED SET MEETING THE GIVEN RESTRICTIONS.

PROBLEM 1.

DRAW AN ARROW DIAGRAM FOR THE FOLLOWING

ACTIVITY	PRECEDED BY	FOLLOWED BY
A	-	B, E
B	A	C, D
C	B	E
D	B	F, G
E	A, C	F
F	D, E	G
G	D, F	-

PROBLEM 2.

DRAW AN ARROW DIAGRAM FOR THE FOLLOWING

ACTIVITY	PRECEDED BY	FOLLOWED BY
A	-	D, E, F
B	-	E, F
C	-	H
D	A	G
E	A, B	G
F	A, B	H
G	D, E	-
H	C, F	-

SOURCE...REFERENCE 7

COMPOSITE ACTIVITIES

LET ACTIVITY A BE A PREDECESSOR OF ACTIVITY B. IN PRACTICE, A IS OFTEN INTERPRETED IN SUCH A WAY THAT B CAN BE STARTED AS SOON AS A IS PARTIALLY COMPLETED. OR, MORE GENERALLY, MANY ACTIVITIES MAY BE STARTED AS SOON AS A IS SOME PERCENTAGE TOWARD COMPLETION. IN THIS SITUATION WE CONSIDER A TO BE A COMPOSITE OF MANY ACTIVITIES. FOR EXAMPLE, IF ACTIVITY C CAN BE STARTED WHEN A IS HALF COMPLETED, ACTIVITY D WHEN A IS THREE-FOURTHS COMPLETED, AND ACTIVITY B WHEN A IS FULLY COMPLETED, WE CONSIDER A TO BE A COMPOSITE OF THREE DIFFERENT ACTIVITIES,A1, A2, AND A3. FIGURE A10. BY USING THIS TECHNIQUE OF REDEFINING ACTIVITIES IN TERMS OF THEIR COMPONENTS WHEN NECESSARY, WE MAY ASSUME THAT EACH JOB IN A PROJECT MAY NOT HAVE TO BE COMPLETED BEFORE ANY OF ITS SUCCESSORS CAN BEGIN.

AGGREGATED ACTIVITIES

SOMETIMES A CERTAIN GROUP OF ACTIVITES MAY BE CONSIDERED AS ONE ACTIVITY. THIS INTERPRETATION MAY BE QUITE DESIRABLE, ESPECIALLY WHEN ALL THE ACTIVITIES IN THE GROUP ARE TECHNOLOGICALLY ORDERED AND CAN BE CONSIDERED TO FORM A SMALL PROJECT IN THEIR OWN RIGHT. WHEN THIS TYPE OF SITUATION OCCURS A SINGLE ACTIVITY MAY BE SUBSTITUTED FOR THE GROUP. FIGURE A11. IN THIS MANNER NETWORKS OF VARIOUS LEVELS OF COMPLEXITY ARE POSSIBLE. THE LEVELS COULD CORRESPOND TO THE LEVELS OF MANAGEMENT TO WHICH REPORTS ARE TO BE SUPPLIED.

LEAD TIME ACTIVITY

EVENTUALLY A PROJECT MUST BE PUT ON THE CALENDAR. IT IS NECESSARY TO INTRODUCE AT LEAST ONE ACTIVITY THAT STARTS AT THE ZERO DATE ON THE CALENDAR AND TERMINATES AT THE START OF THE PROJECT. THIS ACTIVITY IS INTERPRETED AS THE LEAD TIME FOR THE ENTIRE PROJECT. IT MAY BE USED TO AGGREGATE CERTAIN ADMINSTRATIVE MATTERS THAT MUST BE HANDLED BEFORE THE ACTUAL START OF THE PROJECT. USUALLY THE NORMAL DURATION OF LEAD TIME IS THE TIME FROM SOME FIXED CALENDAR DATE TO THE ASSUMED PROJECT START DATE. THE CRASH DURATION IS ZERO. OTHER DURATION LIMITS ARE POSSIBLE, DEPENDING ON THE INTERPRETATION OF LEAD TIME. FOR EXAMPLE, WHEN UPDATING A NETWORK THIS ACTIVITY CAN BE USED TO PLACE THE PROJECT ON A CURRENT BASIS.

DELIVERY RESTRAINTS

CONSIDER THE PROJECT SHOWN IS FIGURE A12. LET THE DURATION OF JOB A BE THREE DAYS. SUPPOSE TO PERFORM JOB B MATERIAL IS NEEDED THAT TAKES TEN DAYS FOR DELIVERY. ONE MIGHT DRAW IN A CONSTRAINT ARROW C-B WITH THE DURATION OF TEN DAYS. THE DIAGRAM WOULD THEN APPEAR AS FIGURE A13.

PROBLEM 3.

DRAW AN ARROW DIAGRAM FOR THE ACTIVITY LIST BELOW:

RENEWING A PIPE LINE EXAMPLE

IDENT	ACTIVITY	PRECEDED BY	FOLLOWED BY
A	ASSEMBLE CREW FOR JOB	-	B
B	USE OLD LINE TO BUILD INVENTORY	A	C
C	MEASURE AND SKETCH OLD LINE	B	E,F,G,H
D	DEVELOP LIST OF MATERIALS	-	H
E	ERECT SCAFFOLD	C	I,K
F	PROCURE PIPES	C	J
G	PROCURE VALVES	C	K
H	DEACTIVATE OLD LINE	C,D	I,K
I	REMOVE OLD PIPE	E,H	L
J	PREFAB NEW PIPE	F	L
K	PLACE VALVES	E,G,H	N,O
L	PLACE NEW PIPE	I,J	M
M	WELD PIPE	L	N,O
N	CONNECT VALVES	K,M	P,Q
O	INSULATE	K,M	Q
P	PRESSURE TEST	N	R
Q	REMOVE SCAFFOLD	N,O	R
R	CLEAN UP AND RELEASE TO CREW	P,Q	-

INTRODUCTION TO SCHEDULING

****

ALTHOUGH PERT IS AN EFFECTIVE MANAGEMENT CONTROL TOOL, IT IS ALSO EFFECTIVE AS A SCHEDULING TOOL BY USING THE VARIATIONS IN PROBABILITY AS A BASIS FOR DETERMINING THE EXPECTED TIME. WHEN A PERT NETWORK IS DEVELOPED IT MUST REPRESENT THE PLAN FOR DOING THE OVERALL TASK AND THE SCHEDULE MUST BE REALISTIC. ONCE ESTABLISHED, IT MUST BE FOLLOWED BY THE ORGANIZATION PERFORMING THE ACTIVITIES.

INTERMEDIATE MILESTONE SCHEDULES ARE IMPORTANT SINCE THEY GENERATE TARGETS OR GOALS TO BE ATTAINED. THEY ARE ESSENTIAL FOR COMMUNICATION BETWEEN PEOPLE PERFORMING THE WORK, SUPPLIERS, PROGRAM MANAGEMENT, TOP MANAGEMENT AND THE CUSTOMER.

ESTABLISHING AND MAINTAINING A GOOD SCHEDULE WILL REQUIRE THE FOLLOWING

- CONSTANT EVALUATION OF PROGRESS.
- GOOD DEFINITION OF ACTIVITIES.
- AWARENESS OF THE EFFECT CREATED BY A DELAY.
- EVENTS SCHEDULED FREQUENTLY.
- A FEELING ON THE PART OF PERSONS WHO MUST MEET THE SCHEDULE THAT THEY HELPED TO ESTABLISH IT.
- POSITIVE MANAGEMENT DIRECTION.

PERT WILL FULFILL THE FIRST FOUR OF THE ABOVE CONSIDERATIONS. THE LAST TWO FACTORS CAN BE ACHIEVED BY MAKING THE INDIVIDUAL OR TEAM FEEL THAT HE HAS PLAYED A PART IN ESTABLISHING THE GOAL. THE PLAN MUST BE THEN ACCEPTED BY MANAGEMENT.

THE INCORPORATION OF A REALISTIC SCHEDULING SYSTEM TAKES THE GUESSWORK OUT OF SETTING SCHEDULES AND PROVIDES MANY OTHER INTERNAL SCHEDULES. THERE SHOULD, HOWEVER, BE ONLY ONE SCHEDULE THAT IS GENERATED OR CHECKED BY PERT.

SCHEDULING WITH SINGLE TIME ESTIMATES
****

BASIC TO THE UTILIZATION OF PERT PLANNING IS THE ARROW DIAGRAM WHICH PICTORIALLY DESCRIBES THE NETWORK OF EVENTS OR ACTIVITIES TO BE PERFORMED IN COMPLETING A PROJECT. IT IS THE SIMULATION, ON PAPER, OF THE TOTAL PROJECT AND THE ORDER IN WHICH EACH ACTIVITY IS TO BE PERFORMED. TIME DURATION ESTIMATES ARE NECESSARY IN ORDER TO SCHEDULE. THESE ESTIMATES ARE ASSIGNED TO EACH JOB WHICH IS REPRESENTED BY AN ARROW.

IN ESTIMATING THE TIME FOR EACH ACTIVITY, THE ESTIMATOR SHOULD RECORD WHO OR WHAT SKILL IS REQUIRED FOR THE TASK, QUANTITY NEEDED, FACILITIES AND MATERIAL REQUIRED AND THE POINT AT WHICH THEY ARE REQUIRED. IT SHOULD BE ASSUMED THAT NORMALLY AVAILABLE OR EXPECTED RESOURCES WILL REMAIN CONSTANT THROUGHOUT THE PROJECT. THE IMPORTANCE OF REALISTIC ESTIMATES CANNOT BE OVEREMPHASIZED.

THE SAME PERSON WHO DETERMINES THE ACTIVITY BETWEEN EVENTS SHOULD ALSO PROVIDE THE ESTIMATES OF ELAPSED TIME FOR PERFORMANCE OF THE ACTIVITY. HE SHOULD HAVE FULL KNOWLEDGE OF A FIXED RESOURCES MIX AVAILABLE TO HIM AND SHOULD BE CAPABLE OF DOING THE ACTIVITY. ONCE SUBMITTED, TIME ESTIMATES SHOULD NOT CHANGE UNLESS THERE IS A CORRESPONDING CHANGE IN WORK CONTENT, RATE OF APPLICATION OF RESOURCES, OR MORE KNOWLEDGE WHICH WOULD IMPROVE ESTIMATES. THESE INCLUDE REVISION OF PLANS, INTRODUCTION OF NEW RESOURCES, CHANGE IN PERSONNEL, TECHNICAL DIFFICULTIES OR BREAKTHROUGHS, AND AUTHORIZATION OF OVERTIME.

PROBLEM 4.

CHECK YOUR ANSWER TO THE RENEW PIPE LINE PROBLEM BY REFERRING TO THE FOLLOWING ACTIVITY DESCRIPTION LIST. PUNCH YOUR SOLUTION AND RUN ON THE COMPUTER.

RENEWING A PIPELINE ACTIVITY DESCRIPTION SHEET

IDENT	ACTIVITY	I	J	TIME
A	ASSEMBLE CREW FOR JOB	1	2	9
B	USE OLD LINE TO BUILD INVENTORY	2	3	30
C	MEASURE AND SKETCH OLD LINE	3	4	2
D	DEVELOP LIST OF MATERIALS	1	5	1
X	DUMMY 1	4	5	0
E	ERECT SCAFFOLD	4	6	2
F	PROCURE PIPES	4	7	34
G	PROCURE VALVES	4	8	45
H	DEACTIVATE OLD LINE	5	6	1
Y	DUMMY 2	6	8	0
I	REMOVE OLD PIPE	6	9	7
J	PREFAB NEW PIPE	7	9	7
K	PLACE VALVES	8	11	1
L	PLACE NEW PIPE	9	10	6
M	WELD PIPE	10	11	2
N	CONNECT VALVES	11	12	1
O	INSULATE	11	13	5
Z	DUMMY 3	12	13	0
P	PRESSURE TEST	12	14	1
Q	REMOVE SCAFFOLD	13	14	1
R	CLEAN UP AND TURN OVER TO CREW	14	15	1

SOURCE...REFERENCE 7

DESCRIPTION OF COMPUTER REPORT INFORMATION

****

ET.....EXPECTED TIME

WHEN USING A SINGLE TIME ESTIMATE THIS IS THE DURATION THAT THE ACTIVITY IS EXPECTED TO REQUIRE.

ES.....EARLIEST START TIME

THE EARLIEST TIME THAT A JOB MAY START AND ASSURE MINIMUM PROJECT COMPLETION TIME. THIS IS COMPUTED BY SUMMING THE ET VALUES FOR ALL JOBS ALONG A PATH LEADING TO THE TAIL NODE OF THE JOB AT HAND. A SUMMATION IS PERFORMED FOR EACH PATH AND THE LARGEST OF THESE IS SET EQUAL TO ES. THE SUMMATIONS ARE PERFORMED STARTING WITH THE FIRST NODE. WHEN REFERRED TO THE EVENT NODES, ES IS THE EARLY START TIME FOR ALL THE JOBS WHOSE TAIL NODE IS THE NODE REFERRED TO. THIS MEANS THAT ALL JOBS LEADING UP TO THAT EVENT NODE MUST BE COMPLETED BEFORE ANY OF THE CONNECTING JOBS, WHOSE TAIL NODES ARE THE SAME AS THE GIVEN EVENT NUMBER, MAY BE STARTED.

EF.....EARLIEST FINISH TIME

THE EARLIEST TIME THAT A JOB MAY BE COMPLETED. THIS IS COMPUTED BY ADDING THE JOBS MEAN TIME ET ALONG THE LONGEST PATH TO THE VALUE OF ES FOR THAT JOB. THIS IS THE EXPECTED COMPLETION TIME FOR THE JOB REPRESENTED BY ITS HEAD NODE EVENT NUMBER.

LF.....LATEST FINISH TIME

THIS IS THE LATEST TIME THAT A JOB MAY FINISH AND ASSURE THAT THE PROJECT WILL BE COMPLETED WITHIN THE SPECIFIED PROJECT COMPLETION TIME. LF IS COMPUTED AT THE LAST NODE AND WORKED BACK TOWARD THE FIRST NODE.

LS.....LATEST START TIME

THE LATEST TIME THAT A JOB MAY START AND ASSURE THE COMPLETION TIME SPECIFIED. STARTING AT THE LAST NODE THIS IS COMPUTED BY SUBTRACTING ES FOR EACH JOB FROM ITS LF.

TF.....TOTAL FLOAT TIME

THE DIFFERENCE BETWEEN LS AND ES FOR A JOB. TF REPRESENTS THE TOTAL FLOAT OR SLACK TIME ALLOWED IN BEGINNING A JOB. IT IS THE LENGTH OF TIME THAT THE START OF A JOB MAY BE DELAYED WITHOUT CHANGING THE MINIMUM PROJECT COMPLETION TIME.

FF.....FREE FLOAT

THE LENGTH OF TIME THAT THE START OF A JOB MAY BE DELAYED WITHOUT CHANGING ES FOR ANOTHER JOB.

SCHEDULING CALCULATIONS FOR EVENTS
****

CALCULATION OF ES AND LF OF EVENTS

1. ES FOR ANY EVENT IS CALCULATED BY DETERMINING THE EXPECTED COMPLETION TIME OF ALL ACTIVITIES LEADING TO THAT EVENT, AND SELECTING THE LATEST SUCH TIME. THIS MEANS THAT ES IS THE EARLIEST TIME AT WHICH ALL PRIOR ACTIVITIES LEADING TO THIS EVENT WILL BE COMPLETED . THUS IN FIGURE A14 ES FOR NODE 6 IS THE LATER OF

   ES OF NODE 4 PLUS DURATION OF 4-6 WHICH IS 12,

   OR

   ES OF NODE 5 PLUS DURATION OF 5-6 WHICH IS 13.

   THERFORE, ES OF NODE 6 IS 13.

2. CALCULATION OF THE ES VALUES MUST PROCEED FROM THE INITIAL EVENT TO LATER EVENTS, SINCE EACH ES DEPENDS ON PREVIOUS EVENTS AND ACTIVITIES.

3. ONCE ALL THE ES VALUES HAVE BEEN CALCULATED, THE TOTAL PROJECT DURATION IS KNOWN. IT IS THE ES FOR THE FINAL EVENT.

4. THE LATEST ALLOWABLE TIME LF FOR EACH EVENT IS CALCULATED IN A MANNER APPROXIMATELY THE REVERSE OF THAT FOR ES. LF FOR ANY EVENT IS THE EARLIEST TIME CALCULATED BY SUBTRACTING THE DURATION OF EACH ACTIVITY DIRECTLY FOLLOWING THE EVENT FROM LF FOR THAT ACTIVITIES TERMINAL EVENT.

   IN FIGURE A15, LF FOR NODE 8 IS THE EARLIER OF

   LF OF NODE 9 MINUS DURATION OF 8-9 WHICH IS 16

   OR

   LF OF NODE 10 MINUS DURATION OF 8-10 WHICH IS 11

   THEREFORE, LF FOR NODE 8 IS 11.

5. CALCULATION OF THE LF VALUES MUST PROCEED FROM THE FINAL EVENT BACK TO EARLIER EVENTS. LF FOR THE INITIAL EVENT MUST BE ZERO OR A CALCULATION ERROR HAS OCCURRED.

6. NOTE THAT THE ES VALUES MUST BE CALCULATED PRIOR TO THE LF VALUES, TO OBTAIN A STARTING VALUE FOR THE LF VALUES. LF FOR THE FINAL EVENT EQUALS ES FOR THAT EVENT.

MANUAL CALCULATION OF ES AND LF
••••••••••••••••••••••••••••••

1. THE FOLLOWING DISCUSSION SUMMARIZES A CONVENIENT SCHEME FOR HAND COMPUTATION OF THE ES VALUES AND LF VALUES, FOLLOWING THE LOGIC OUTLINED EARLIER.

   1.1 CONSTRUCT A MATRIX IN WHICH ARROW HEADS APPEAR AS COLUMN J IDENTIFICATION AND TAILS AS ROW I IDENTIFICATION. SEE FIGURE A16.

   1.2 PLACE THE DURATION OF EACH ACTIVITY AIJ IN ITS PROPER BOX WITHIN THE MATRIX. NOTE THAT THERE ARE NEVER ANY VALUES BELOW THE DIAGONAL.

   1.3 ES FOR EVENT 1 IS ZERO.

   1.4 CALCULATE ES FOR EVENT 2 BY DETERMINING THE LONGEST DURATION. THAT IS THE LARGEST NUMBER IN COLUMN 2 FOR ALL ACTIVITIES WHICH END AT EVENT 2. RECORD THIS DURATION TO THE LEFT OF ROW 2.

   1.5 DETERMINE THE QUANTITIES OBTAINED BY ADDING EACH DURATION IN COLUMN 3, THAT IS ALL ACTIVITIES ENDING AT EVENT 3, TO ES FOR THE ROW IN WHICH THAT DURATION APPEARS, THAT IS IS TO ES FOR THE EVENT PRECEDING THAT ACTIVITY. ES FOR EVENT 3 IS THE LARGEST OF THESE QUANTITIES.

   1.6 CALCULATE ES FOR EACH SUCCEEDING EVENT IN A MANNER ANALOGOUS TO 1.5.

   1.7 CALCULATE LF FOR THE LAST EVENT BY SETTING IT EQUAL TO ES. RECORD UNDER THE COLUMN CORRESPONDING TO THAT EVENT.

   1.8 CALCULATE LF FOR THE NEXT PRECEDING EVENT. DETERMINE THE QUANTITIES RESULTING WHEN EACH DURATION IN THE ROW CORRESPONDING TO THE EVENT UNDER CONSIDERATION IS SUBTRACTED FROM LF IN THE COLUMN IN WHICH THAT DURATION APPEARS. LF IS THE SMALLEST OF THESE QUANTITIES. THAT IS, THE EARLIEST DATE AT WHICH AN ACTIVITY STARTING AT THAT EVENT MUST BEGIN TO MAINTAIN SCHEDULE.

   1.9 REPEAT FOR EACH EVENT, PROCEEDING FROM HIGHER NUMBERED EVENTS TO LOWER.

PROBLEM 5.

DRAW THE ARROW DIAGRAM FOR THE FOLLOWING ACTIVITY LIST. CALCULATE ES AND LF. CHECK BY RUNNING THE PROBLEM ON A COMPUTER.

ACTIVITY	I	J	TIME
A	1	2	3
B	2	3	4
C	2	4	5
D	3	5	2
E	4	5	3
F	4	6	4
G	5	7	1
H	6	7	3

SOLUTION IS SHOWN BY FIGURE A17

EVENT SLACK

1. EVENT SLACK IS THE AMOUNT OF LEEWAY AVAILABLE IN REACHING AN EVENT. IT IS CALCULATED BY SUBTRACTING ES FROM LF.

2. IN FIGURE A17, SLACK FOR EVENT 3 IS 12 MINUS 7 WHICH IS 5. NOTE THAT THIS IS THE AMOUNT BY WHICH EVENT 3 CAN BE DELAYED WITHOUT DELAYING PROJECT COMPLETION.

THE CRITICAL PATH

1. THERE WILL BE IN ANY PROJECT ONE CONTINUOUS SEQUENCE OF EVENTS, EACH OF WHICH HAS ZERO SLACK. THIS SEQUENCE, OR PATH, OF EVENTS IS CRITICAL IN THAT DELAY OF ANY OF THESE EVENTS WILL CAUSE PROJECT COMPLETION DELAY.

2. IN FIGURE A17 THE CRITICAL PATH IS 1,2,4,6,7. EACH OF THESE EVENTS HAS ZERO SLACK. ALL OTHER EVENTS HAVE NON-ZERO SLACK.

3. NOTICE THAT THE ACTIVITIES ALONG THE CRITICAL PATH ARE THE SIGNIFICANT ITEMS. THAT IS, DELAY IN ACTIVITIES 1-2,2-4,4-6, OR 6-7 WILL CAUSE THE PROJECT TO MISS ITS COMPLETION DATE. EACH OTHER ACTIVITY CAN BE DELAYED WITH NO CHANGE IN OVERALL PROJECT COMPLETION. THE AMOUNT OF DELAY POSSIBLE FOR EACH OF THESE ACTIVITIES CAN BE CALCULATED. IT IS THE ACTIVITY SLACK.

THE CRITICAL PATH CALCULATION PRODUCES AN IDEALIZED SCHEDULE FOR PROJECT COMPLETION WITHOUT REGARD TO MANPOWER RESOURCES. THE CRITICAL PATH IS THE LONGEST PATH THROUGH THE NETWORK. IT DETERMINES THE TOTAL

MINIMUM LENGTH OF TIME TO ACCOMPLISH THE PROJECT. THERE ARE MANY OTHER PATHS THROUGH THE NETWORK, BUT ALL HAVE A SHORTER DURATION THAN THE CRITICAL PATH. THE TOTAL TIME OF THE CRITICAL PATH MAY BE INCREASED OR DECREASED BY CHANGING THE DURATION OF ANY ACTIVITY ON THE CRITICAL PATH. IF THE CALCULATED TOTAL PROJECT DURATION DOES NOT MEET MANAGEMENTS OBJECTIVES, THE NETWORK MUST BE REPLANNED. THERE ARE TWO THINGS THAT MAY BE DONE TO SHORTEN THE DURATION OF A PROJECT

1. APPLY MORE RESOURCES TO AN ACTIVITY AND THEREBY REDUCE ITS DURATION.
2. REARRANGE THE SEQUENCE OF ACTIVITIES SO THAT MORE ACTIVITIES ARE BEING PERFORMED IN PARALLEL.

THE CRITICAL PATH CALCULATIONS ARE REPEATED AND THE NETWORK IS REPLANNED UNTIL THE PROJECT DURATION MEETS MANAGEMENTS OBJECTIVES. IT MUST BE REMEMBERED THAT THE CRITICAL PATH SCHEDULE TELLS THE EARLIEST A PROJECT COULD BE COMPLETED.

PROBLEM 6.

DETERMINE THE CRITICAL PATH AND EVENT SLACKS FOR THE EXAMPLE OF FIGURE A17. CHECK WITH YOUR COMPUTER SOLUTION.

SCHEDULING CALCULATIONS FOR ACTIVITIES
****

1. THE RESULTS MAY BE ORIENTED TO ACTIVITIES RATHER THAN EVENTS, BY CALCULATING CERTAIN ADDITIONAL QUANTITIES. THESE ACTIVITY FACTORS ARE THE NORMAL OUTPUT FROM A CRITICAL PATH PROGRAM SINCE THEY APPLY DIRECTLY TO THE PHYSICAL ACTIVITIES TO BE PERFORMED.

    1.0 ETIJ IS THE DURATION OF ACTIVITY AIJ.

    1.1 ESIJ IS THE EARLIEST START TIME FOR AIJ.

    1.2 LFIJ IS THE LATEST FINISH TIME FOR AIJ STILL MEETING PROJECT COMPLETION SCHEDULE

    1.3 EFIJ IS THE EARLIEST FINISH TIME FOR AIJ

    1.4 LSIJ IS THE LATEST START TIME FOR AIJ, STILL MEETING PROJECT COMPLETION SCHEDULE

    1.5 TFIJ IS THE TOTAL FLOAT OR ACTIVITY SLACK FOR AIJ

    1.6 FFIJ IS THE FREE FLOAT OR SLACK FOR AIJ. THAT IS, THE AMOUNT OF THIS ACTIVITYS SLACK WHICH HAS NO EFFECT ON ANY OTHER ACTIVITY.

2. THESE QUANTITIES CAN BE CALCULATED BY THE FOLLOWING FORMULAS.

    2.1 ESIJ EQUALS ESI

    2.2 LFIJ EQUALS LFJ

    2.3 EFIJ EQUALS ESI PLUS ETIJ

    2.4 LSIJ EQUALS LFJ MINUS ETIJ

    2.5 TFIJ EQUALS LFJ MINUS ESI MINUS ETIJ

    2.6 FFIJ EQUALS ESJ MINUS ESI MINUS ETIJ

PROBLEM 7.

CALCULATE THE ACTIVITY ORIENTED FACTORS OF ES, LF, EF, LS, TF AND FF FOR THE EXAMPLE SHOWN IN FIGURE A17. CHECK WITH YOUR COMPUTER SOLUTION.

PROBLEM 8.

GIVEN THE DATA BELOW. DRAW THE ARROW DIAGRAM, CALCULATE ES AND LS AND SLACK FOR EACH EVENT. CALCULATE EF,LF,TF,AND FF FOR EACH ACTIVITY. DETERMINE THE CRITICAL PATH. CHECK YOUR ANSWERS BY RUNNING THE PROBLEM ON THE COMPUTER.

IDENT	ACTIVITY	TIME	PREDECESSORS	SUCCESSORS
A	RECEIVE & LOG ORDER	1	-	B,D,J
B	COPY & PRICE ORDER	2	A	C,E
C	EXTEND,CREATE INVOICE	2	B	I
D	CHECK INVENTORY	3	A	F
J	CHECK CUSTOMERS CREDIT	4	A	H
E	SEND ORDER TO WAREHOUSE	2	B	F
F	PICK ITEMS	5	D,E	G
G	PACK ORDER	1	F	H
H	SHIP TO CUSTOMER	3	G,J	I
I	BILL CUSTOMER	1	C,H	-

PROBLEM 9.

GIVEN THE DATA BELOW, DRAW THE ARROW DIAGRAM AND PREPARE DATA FOR A COMPUTER PROGRAM TO DETERMINE THE CRITICAL PATH. RUN YOUR NETWORK ON THE COMPUTER.

IDENT	ACTIVITY	TIME	PREDECESSORS	SUCCESSORS
A	BASEMENT	5	-	B,S
B	FRAME HOUSE	5	A	C,D,E,F,G,H,I
C	ROUGH ELECTRICAL	2	B	J
D	ROUGH PLUMBING	3	B	J
E	ROOFING	2	B	U
F	CHIMNEY	1	B	J
G	SIDING	3	B	L
H	HARDWOOD FLOORS	3	B	K
I	WINDOWS AND DOORS	2	B	K,L
J	WALLBOARD	4	C,D,F	K,M,O
K	TRIM WOOD	2	H,I,J	N,P
L	PAINT EXTERIOR	5	G,I	U
M	PAINT CEILINGS	2	J	N
N	PAINT INTERIOR WALLS	5	K,M	R
O	KITCHEN CABINETS	1	J	P,Q
P	FINISHED PLUMBING & HEAT	2	K,O	U
Q	FINISHED ELECTRICAL	1	O	U
R	FINISH FLOORS	4	N	U
S	LANDSCAPE	3	A	T
T	SEED,ETC.	1	S	U
U	DELIVER HOME	0	E,L,P,Q,R,T	-

SCHEDULING WITH THREE TIME ESTIMATES

****

MANY UNCERTAINTIES AFFECT THE TIMES REQUIRED FOR ACTIVITIES IN A RESEARCH AND DEVELOPMENT PROJECT. THE PRECISE TIME FOR COMPLETION OF A RESEARCH TASK IS UNKNOWN. THE QUESTION THEN ARISES AS TO HOW CAN SUCH A PROJECT BE SCHEDULED. THE ANSWER IS THAT WE MUST WORK WITH ESTIMATES INSTEAD OF STANDARDS. THE PERT TECHNIQUE AS DEVELOPED BY THE NAVY RECOGNIZES THE UNCERTAINTIES IN ESTIMATING TIME FOR COMPLETION OF A RESEARCH TASK AND ATTEMPTS TO QUANTIFY THIS UNCERTAINTY. THIS IS DONE BY OBTAINING THREE ESTIMATES OF COMPLETION TIME FROM THE GROUP RESPONSIBLE FOR COMPLETING THE ACTIVITY.

THE INITIAL INFORMATION WHICH MUST BE SUPPLIED TO THE PERT PROGRAM IS

1. A COMPLETE LIST OF ALL JOBS TO BE PERFORMED IN ORDER TO COMPLETE THE PROJECT.

2. THREE ESTIMATES OF TIME DURATION NEEDED TO COMPLETE EACH JOB

    2.1 A-WHICH IS THE OPTIMISTIC TIME. THIS IS THE SHORTEST POSSIBLE TIME IN WHICH THE ACTIVITY CAN BE ACCOMPLISHED. THIS ESTIMATE WOULD BE ATTAINED ONLY IF EXCEPTIONALLY GOOD LUCK WAS HAD AND EVERYTHING WORKED THE FIRST TIME. THIS DURATION SHOULD BE LESS THAN THE ACTUAL TIME IN 99% OF THE CASES.

    2.2 M-WHICH IS THE MOST LIKELY TIME. THIS IS THE TIME ESTIMATE WHICH WOULD BE MADE IF ONLY ONE WERE REQUESTED. IT IS ALSO THE TIME THAT WOULD OCCUR MOST OFTEN IF THE ACTIVITY WERE REPEATED UNDER EXACTLY THE SAME CONDITIONS MANY TIMES OR IT IS THE ONE THAT WOULD BE GIVEN MOST OFTEN IF MANY QUALIFIED PEOPLE WERE ASKED.

    2.3 B-WHICH IS THE PESSIMISTIC TIME. THIS THE LONGEST TIME THAT THE ACTIVITY WOULD TAKE. IT SHOULD BE A TIME THAT IS EXCEEDED NO MORE THAN ONCE IN A HUNDRED OCCASIONS.

IN ESTIMATING THE TIME FOR EACH ACTIVITY, THE ESTIMATOR SHOULD RECORD WHO OR WHAT SKILL IS REQUIRED FOR THE TASK, QUANTITY NEEDED, FACILITIES AND MATERIAL REQUIRED AND THE POINT AT WHICH THEY ARE REQUIRED. IT SHOULD BE ASSUMED THAT NORMALLY AVAILABLE OR EXPECTED RESOURCES WILL REMAIN CONSTANT THROUGHOUT THE PROGRAM. THE IMPORTANCE OF A REALISTIC ESTIMATE CANNOT BE OVER-EMPHASIZED. THE THREE ESTIMATES DETERMINE THE SHAPE OF A NORMAL DISTRIBUTION CURVE UPON WHICH THE RESULTS OF THE PERT PROGRAM ARE BASED. NOTE FIGURE 80.

SCHEDULING CALCULATIONS FOR THREE TIME ESTIMATES

****

ET.....MEAN DURATION TIME

THE PROBABLE MEAN DURATION TIME FOR EACH JOB BASED ON THE THREE TIME ESTIMATES. THE FORMULA FOR CALCULATING ET AND AN EXAMPLE IS SHOWN IN FIGURE B1.

TE.....EXPECTED COMPLETION TIME

THIS TIME IS EQUAL TO THE LARGEST VALUE OF EF OUT OF ALL THE JOBS LEADING UP TO THAT NODE. TE, THEREFORE, REPRESENTS THE EARLY START TIME FOR ALL JOBS WHOSE TAIL NODE IS THE SAME AS THE GIVEN NODE.

TS.....SCHEDULED TIME OR DATE

THIS IS A TARGET TIME FOR THE COMPLETION OF AN ACTIVITY. IT REFERS TO THE J EVENT NODE. IT IS ASSIGNED TO CERTAIN MILESTONE EVENTS AND CAN BE USED TO CHECK PROJECT PROGRESS.

TS-TE.....SCHEDULED SLACK TIME

THIS IS THE AMOUNT OF TIME AN EVENT CAN BE DELAYED AND STILL MEET THE SCHEDULE DATE. THIS IS ONE OF THE MOST IMPORTANT ATTRIBUTES OF PERT IN TELLING MANAGEMENT WHETHER A PROJECT IS ON, AHEAD OF, OR BEHIND SCHEDULE. IT INDICATES TO THE MANAGER THOSE AREAS WHERE MANPOWER AND/OR FUNDS CAN BE SHIFTED TO A MORE CRITICAL AREA OF THE NETWORK IF NECESSARY.

VARET.....VARIANCE OF THE MEAN DURATION OF AN ACTIVITY.

THIS NUMBER IS CALCULATED BY THE FORMULA SHOWN IN FIGURE B2. THE VARIANCE IS A STATISTICAL TERM USED TO DESCRIBE THE UNCERTAINITY ASSOCIATED WITH THE ACTIVITY. IF THE VARIANCE IS LARGE, FOR EXAMPLE WHEN THE OPTIMISTIC AND PESSIMISTIC ESTIMATES ARE FAR APART, THERE IS GREAT UNCERTAINTY AS TO THE TIME AT WHICH THE ACTIVITY WILL BE COMPLETED. IF THE VARIANCE IS SMALL, THE UNCERTAINTY IS SMALL.

VARTE....VARIANCE OF EXPECTED COMPLETION TIME

THIS NUMBER IS CALCULATED BY THE FORMULA SHOWN IN FIGURE B3. IT IS THE SUM OF THE VARET VALUES OF THE ACTIVITIES THAT WERE USED IN OBTAINING THE TE FOR THE ACTIVITY.

PK.....PROBABILITY OF MEETING ASSIGNED SCHEDULE TIME

PROBABILITY IS COMPUTED BY DETERMINING THE AREA UNDER THE NORMAL DISTRIBUTION CURVE UP TO THE POINT IN QUESTION TS OR TE. THE TOTAL AREA FROM MINUS INFINITY TO PLUS INFINITY IS ONE UNIT.

IT IS LOOKED UP IN A TABLE OF NORMAL PROBABILITIES SUCH AS THAT SHOWN IN FIGURE B5. THE FORMULA FOR CALCULATING THE K VALUE FOR ENTRY TO THIS TABLE IS ILLUSTRATED IN FIGURE B4.

PK THEN IS THE PROBABILITY OF MEETING THE ASSIGNED SCHEDULED TIME.

IF TS EQUALS TE IT MIGHT BE EXPECTED AT FIRST THOUGHT THAT THIS WOULD MEAN A 100% CHANCE OF COMPLETING THE JOB IN THE EXPECTED TIME, TE. THIS IS TRUE AS FAR AS THE RELATION BETWEEN TS AND TE, BUT AS FAR AS TE ITSELF IS CONCERNED, WE MUST NOW CONSIDER THE PROBABILITY OF ACTUALLY COMPLETING THE JOB IN TE TIME, WHICH, SINCE TE HAS DEVIATION ASSOCIATED WITH IT, WOULD TURN OUT TO BE .500 OR 50% . THIS INHERENT PROBABILITY ASSOCIATED WITH TE COMES ABOUT DUE TO THE FACT THAT TE LIES HALFWAY THROUGH THE AREA OF THE DISTRIBUTION CURVE.

IF A SCHEDULED DATE, TS, WERE ASSIGNED WHICH WAS GREATER THAN TE, THE CHANCES OF COMPLETING THE JOB ASSOCIATED WITH TE IN THE TIME, TS, WOULD BECOME GREATER UNTIL FINALLY IT WOULD APPROACH 1.000 OR 100% . THIS IS SHOWN BY FIGURE B6.

IF TS WERE LESS THAN TE THE PROBABILITY WOULD LESSEN UNTIL IT WOULD APPROACH .000 WHERE TS WOULD BE COMPLETELY TO THE LEFT OF THE DISTRIBUTION CURVE. THIS IS SHOWN BY FIGURE B6.

WHEN IT IS DESIRABLE TO DETERMINE WHAT CHANCE OR WHAT THE PROBABILITY IS OF COMPLETING AN ACTIVITY OF SOME ASSIGNED SCHEDULED TIME, TS, OTHER THAN THE EXPECTED COMPLETION TIME, TE, THE PROCEDURE WOULD BE TO DETERMINE HOW MANY STANDARD DEVIATIONS TS WAS AWAY FROM TE. FOR EACH AMOUNT OF DEVIATION AWAY FROM THE MEAN THERE IS A VALUE OF PROBABILITY REPRESENTED BY AREA UNDER THE NORMAL CURVE. THE AMOUNT OF STANDARD DEVIATIONS THAT TS IS AWAY FROM TE WOULD THEN BE LOOKED UP IN THE TABLE SHOWN IN FIGURE B4.

IT SHOULD BE NOTED THAT ALTHOUGH THE PROBABILITY NEVER REACHES ZERO, ONLY AT INFINITY, IT IS CONSIDERED AS SUCH IF TS WERE 3 OR MORE STANDARD DEVIATIONS AWAY FROM TE AS SHOWN IN FIGURE B6. TO DETERMINE HOW MANY STANDARD DEVIATIONS TS IS AWAY FROM TE THE FORMULA SHOWN IN FIGURE B4 IS USED.

TF.....TOTAL FLOAT

TOTAL FLOAT MAY BE POSITIVE INDICATING A DELAY IN THE STARTING OF A JOB. IT MAY BE NEGATIVE IF A PROJECT COMPLETION TIME HAS BEEN ASSIGNED WHICH IS LESS THAN THE MINIMUM PROJECT COMPLETION TIME. IN SUCH A CASE THE NEGATIVE TF INDICATES THAT THE JOB WILL BE BEHIND SCHEDULE.

TF MAY ALSO BE ZERO INDICATING THAT THE JOB MUST BE STARTED AT EARLY START TIME IF THE PROJECT IS TO BE COMPLETED IN MINIMUM TIME. ZERO SLACK IS INDICATED BY AN ASTERISK *.

IF A PROJECT COMPLETION TIME HAS BEEN ASSIGNED WHICH IS GREATER THAN THE MINIMUM COMPLETION TIME THEN ALL TOTAL FLOAT TIME WILL BE POSITIVE. IF A PROJECT COMPLETION TIME HAS BEEN ASSIGNED WHICH IS LESS THAN THE MINIMUM COMPLETION TIME THEN TOTAL FLOAT MAY BE POSITIVE, NEGATIVE, OR ZERO.

PROBLEM 10.

DRAW AN ARROW DIAGRAM FOR THE FOLLOWING ACTIVITY LIST. CALCULATE ET VALUES. RUN ON A COMPUTER AND CHECK RESULTS. DETERMINE CRITICAL PATH.

I	J	A	M	B
8	1	5	7	10
8	3	10	12	15
8	6	8	9	15
1	2	11	15	17
2	4	3	4	5
4	11	0	0	0
3	4	15	20	25
6	4	21	24	30
7	5	25	30	35
4	5	12	15	20
11	5	10	12	14
1	3	1.5	3.0	3.5
6	7	15	18	20
2	11	5	8	10

PROBLEM 11.

ASSIGN A PROJECT COMPLETION DATE OF 50 TO THE PROBLEM OUTLINED IN PROBLEM 10. RUN ON COMPUTER. WHAT IS MEANT BY THE NEGATIVE SLACK.

PROBLEM 12.

ASSIGN A PROJECT COMPLETION DATE OF 50, AND SCHEDULED DATES OF 15 TO ACTIVITY 8-3, 50 TO 7-5, AND 30 TO 6-7. RUN ON COMPUTER. WHAT IS THE PROBABILITY OF ATTAINING THE SCHEDULED DATES. VERIFY THE CALCULATED PROBABILITY OF 8-3 BY CALCULATING PK AND REFERRING TO FIGURE B4.

PROBLEM 10 OUTPUT

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     THIS RUN HAS NO COMPLETION DATE AND NO SCHEDULED DATES ASSIGNED.
 AN  *  UNDER THE TF COLUMN REPRESENTS A CRITICAL PATH ACTIVITY.

-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 I-J *  ET *  A  *  M  *  B  *  ES *  EF *  LS *  LF *  TF *  FF *
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 8-1 * 7.17* 5.00* 7.00*10.00* 0.00* 7.17*12.33*19.50*12.33* 0.00*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 8-3 *12.17*10.00*12.00*15.00* 0.00*12.17*10.16*22.33*10.16* 0.00*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 8-6 * 9.83* 8.00* 9.00*15.00* 0.00* 9.83* 0.00* 9.83****** 0.00*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 1-2 *14.67*11.00*15.00*17.00* 7.17*21.84*23.16*37.83*15.99* 0.00*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 2-4 * 4.00* 3.00* 4.00* 5.00*21.84*25.84*38.33*42.33*16.49* 8.49*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 1-11* 0.00* 0.00* 0.00* 0.00*34.33*34.33*45.66*45.66*11.33* 0.00*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 3-4 *20.00*15.00*20.00*25.00*12.17*32.17*22.33*42.33*10.16* 2.16*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 6-4 *24.50*21.00*24.00*30.00* 9.83*34.33*17.83*42.33* 8.00* 0.00*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 7-5 *30.00*25.00*30.00*35.00*27.66*57.66*27.66*57.66****** 0.00*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 4-5 *15.33*12.00*15.00*20.00*34.33*49.66*42.33*57.66* 8.00* 8.00*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
11-5 *12.00*10.00*12.00*14.00*34.33*46.33*45.66*57.66*11.33*11.33*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 1-3 * 2.83* 1.50* 3.00* 3.50* 7.17*10.00*19.50*22.33*12.33* 2.17*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 6-7 *17.83*15.00*18.00*20.00* 9.83*27.66* 9.83*27.66****** 0.00*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 2-11* 7.83* 5.00* 8.00*10.00*21.84*29.67*37.83*45.66*15.99* 4.66*
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*
 I-J *  ET *  A  *  M  *  B  *  ES *  EF *  LS *  LF *  TF *  FF *
-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*

                              PROJECT COMPLETION   57.66
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RESCHEDULING METHOD

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ONE REASONABLE APPROACH TO RESCHEDULING IS TO EXTEND THE SCHEDULED DATE OF THE OBJECTIVE EVENT. IF THE SCHEDULED DATE OF THE OBJECTIVE EVENT IS CHANGED, THE LATEST TIMES FOR ALL EVENTS MUST BE RECOMPUTED.

IF THE LATEST TIME OCCURS BEFORE THE EXPECTED TIME, SET THE SCHEDULED DATE AT THE LATEST TIME. OTHERWISE, SET THE SCHEDULED DATE FOR THE EVENT AT THE POINT WHICH MAXIMIZES THE PROBABILITY OF ITS BEING MET WITHIN THE SLACK INTERVAL.

AFTER ESTABLISHING THE NEW SCHEDULE, APPRAISE FUTURE POSSIBILITIES BY RECOMPUTING THE PROBABILITIES OF NO SLACK IN THE SYSTEM. THE USE OF PROBABILITY VARIES AMONG PROGRAMS. FOR EXAMPLE, IF THE PROBABILITY OF NO SLACK IS IN EXCESS OF 0.5, REDEPLOYMENT OF RESOURCES AND/OR CHANGES IN PERFORMANCE SHOULD BE CONSIDERED. IF THE PROBABILITY IS APPROXIMATELY 0.5, MANAGEMENT SHOULD CLOSELY MONITOR PROGRESS. IF THE PROBABILITY OF NO SLACK IS LESS THAN 0.5, PROGRESS SHOULD RECEIVE ONLY ROUTINE CHECKING.

BY USING THIS METHOD OF RESCHEDULING, REPLANNING BECOMES A CONTINUOUS PART OF THE PERT PROGRAM. THEREFORE, PROGRAM REDUCTION IS ACCOMPLISHED BY REPLANNING, ELIMINATION OF DESIRABLE BUT UNNECESSARY ACTIVITIES, THE ASSUMPTION OF TECHNOLOGICAL RISK, OR THE UTILIZATION OF PARALLEL DEVELOPMENT.

OFTEN A SCHEDULE WILL BE DETERMINED FOR THE COMPLETION OF THE OBJECTIVE EVENT AND/OR OTHER STRATEGIC EVENTS. THE NETWORK COMPUTATION DESCRIBED THUS FAR PROVIDES A BASIS FOR DETERMINING THE LEVEL OF RISK INVOLVED IN MEETING SUCH A SCHEDULED DATE, TS. PERT CAN BE USED TO DETERMINE THE RISK INVOLVED IN COMPLETING A GIVEN ACTIVITY, IN COMPLETING A PORTION OF A PROJECT, OR IN COMPLETING AN ENTIRE PROJECT. THESE CALCULATIONS PERMIT THE ADJUSTMENT OF A SCHEDULE SO AS TO ARRIVE AT A LEVEL OF RISK ACCEPTABLE TO MANAGEMENT.

IN ORDER FOR MANAGEMENT TO USE THIS PROBABILITY INFORMATION, LATE PERFORMANCE MUST BE EVALUATED BY COST PENALITIES AND OTHER KINDS OF PENALTIES FOR FAILURE TO MEET OBLIGATIONS. THE PROBABILITIES OBTAINED PROVIDE ONLY PART OF THE INFORMATION NEEDED FOR MANAGEMENT DECISIONS.

AN ADVANTAGE OF PERT IS THAT THIS SAME CLASS OF CALCULATIONS OF PROBABILITY CAN BE USED FOR POSITIVE MANAGEMENT PLANNING TO ESTABLISH DATES AS WELL AS TO ADAPT TO GIVEN DATES. ONCE A MANAGEMENT POLICY IS ESTABLISHED AS TO WHAT CONSTITUTES A DESIRABLE LEVEL OF RISK IN MEETING SCHEDULES, A SCHEDULE CAN BE DEVELOPED WHICH IS BASED ON THAT POLICY AND WHICH USES THE BASIC PERT NETWORK DATA. FOR EACH ACTIVITY AN APPROPRIATE DATE WOULD BE DETERMINED HAVING THE SAME GIVEN LEVEL OF RISK.

SOURCE...REFERENCE 5

ANALYSIS OF THE NETWORK

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TO BE EFFECTIVE, THE ENTIRE PROJECT MUST BE INCORPORATED INTO ONE NETWORK. OTHERWISE THE CRITICAL PATH THROUGH CONNECTING EVENTS MAY NOT BE EVIDENT. NOTE FIGURE B7.

ANALYSIS IS THE EVALUATION OF ORIGINAL PLANS IN LIGHT OF CURRENT OPERATING CONDITIONS. IT WILL INDICATE THE VALUE OF VARIOUS ALTERNATIVES AND THEIR EFFECT ON OBJECTIVES. TO BE EFFECTIVE, ANALYSIS SHOULD START EARLY IN A PROJECT AND CONTINUE THROUGHOUT IT.

THE EFFECTIVENESS OF AN EVALUATION SYSTEM IS MEASURED BY THE SPEED WITH WHICH OUT-OF-PHASE SITUATIONS CAN BE RECOGNIZED AND CORRECTED. TO PERMIT THIS, PERT CAN BE PROGRAMMED ON DIFFERENT COMPUTER SYSTEMS.

NETWORK ANALYSIS SHOULD BE IN KEEPING WITH AN ESTABLISHED MANAGEMENT POLICY REGARDING THE LEVEL OF RISK TO BE ASSUMED IN MEETING SCHEDULE DATES. UPON COMPLETION OF THE ANALYSIS, TOP LEVEL MANAGEMENT OR THE TECHNICAL DIRECTION STAFF MAY CHOOSE TO /1/ MAKE ADJUSTMENTS AND TRADE OFFS IN PLANS, SCHEDULES, RESOURCES, OR PERFORMANCE SPECIFICATIONS, OR /2/ TEST THE EFFECTS OF DIFFERENT DECISIONS BY SIMULATING EACH ON THE COMPUTER.

SOURCE...REFERENCE 5

REVISED PLANS
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AFTER EXAMINING INITIAL COMPUTER OUTPUTS FOR A PARTICULAR COMPONENT OR SUBSYSTEM, MANAGEMENT MAY DECIDE TO DEVELOP AND TEST HYPOTHETICAL PLANS. THOSE EVENTS THAT ARE MARKED AS PROBABLY BEING REACHED AHEAD OF SCHEDULE INDICATE POSSIBLE AREAS WHERE RESOURCE TRADE-OFFS MIGHT BE ARRANGED. EVENTS ALONG THE CRITICAL PATH INDICATE POSSIBLE AREAS FOR REDUCTION IN PERFORMANCE REQUIREMENTS OR INCREASED RESOURCE APPLICATION.

IF THE SCHEDULE FOR A MAJOR EVENT IS JEOPARDIZED, IT MAY BE POSSIBLE TO REPLAN AND THUS IMPROVE THE OUTLOOK FOR MEETING THE SCHEDULE. THIS REPLANNING COULD TAKE THE FORM OF ALTERING THE SEQUENCE OF EVENTS AND THUS POSTPONING CERTAIN ACTIVITIES TO A LATER POINT IN TIME. FOR EXAMPLE, IT MIGHT BE POSSIBLE IN CERTAIN SITUATIONS TO FOREGO SOME TESTING BEFORE A FLIGHT. THUS REPLANNING WOULD NOT FORCE THE FLIGHT TO AWAIT ALL THE PRELIMINARY TESTS THAT WERE ORIGINALLY PLANNED.

IN ADDITION TO THE CHANGES ALREADY MENTIONED, IT IS POSSIBLE TO SET UP THE COMPUTER SO THAT IT WILL DEVELOP A NEW SCHEDULE BASED ON SOME ARBITRARY SET OF CRITERIA. DATA ON SUCH CHANGES CAN BE READ INTO THE COMPUTER AND THE ANALYSIS QUICKLY PERFORMED.

SOURCE...REFERENCE 5

INTRODUCTION TO RESOURCE SCHEDULING
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SCHEDULING HAS ALWAYS BEEN A PROBLEM TO INDUSTRY. THE SCHEDULING PROBLEM IS A DYNAMIC PROGRAMMING TYPE PROBLEM. IT IS A DYNAMIC PROGRAMMING TYPE PROBLEM BECAUSE THE DECISION FOR SCHEDULING A TASK, WHICH USES CERTAIN FACILITIES IN ONE TIME PERIOD, WILL AFFECT THE CONDITIONS UNDER WHICH OTHER TASKS MUST BE SCHEDULED IN PERIODS LATER. AS YET THERE ARE NO TECHNIQUES WHICH WILL DERIVE AN OPTIMUM SCHEDULE UNDER REALISTIC CONDITIONS.

UNTIL RECENTLY SCHEDULERS USED TECHNIQUES WHICH SCHEDULE A TASK WITHOUT CONSIDERING THE RELATIONSHIPS OF THIS TASK WITH SUCCEEDING TASKS. THE RESULTING SCHEDULE WAS A FEASIBLE SCHEDULE WHICH ACCOMPLISHED THE OVERALL PROJECT, BUT IT ALMOST ALWAYS RESULTED IN A SCHEDULE WHICH TOOK LONGER TO ACCOMPLISH THAN AN OPTIMAL SCHEDULE WHOULD HAVE TAKEN. WITH THE ADVENT OF PERT INDUSTRY WAS FINALLY ABLE TO OPTIMALLY SCHEDULE PROJECTS. UNFORTUNATELY PERT ASSUMES THAT INFINITE OR UNLIMITED RESOURCES ARE AVAILABLE. AS A CONSEQUENCE WHEN THE USER TRIES TO EMPLOY THE RESULTING PERT SCHEDULE HE MIGHT FIND THAT TWO OR MORE JOBS ARE SCHEDULED TO START ON THE SAME DAY, AND THESE JOBS ALL REQUIRE THE SAME PIECE OF EQUIPMENT OR SKILLED WORKER, AND THERE IS ONLY ONE OF THESE PIECES OF EQUIPMENT OR WORKER AVAILABLE.

THE PRECEDING SITUATION RESULTS IN A CONFLICT. THIS CONFLICT WILL MAKE THE PERT SCHEDULE INOPERABLE AT THE POINT IN TIME THIS CONFLICT ARISES. CERTAIN JOBS MUST BE DELAYED IN RELATION TO THE SCHEDULE AT THE TIME OF THIS CONFLICT. THIS DELAYING OF JOBS AND THE DELAYING OF OTHER JOBS DUE TO OTHER CONFLICTS ARISING DURING THE COURSE OF THE OVERALL PROJECT MAY RESULT IN THE EXTENSION OF THE OVERALL DURATION OF THE PROJECT. DEPENDING ON THE DECISIONS AS TO WHICH JOBS TO DELAY AND WHICH TO START AT EACH CONFLICT, THE SCHEDULE MAY CAUSE THE OVERALL PROJECT TO BE COMPLETED IN A PERIOD OF TIME VARYING FROM A MINIMUM AMOUNT OF TIME TO A LONGER PERIOD. THE LENGTH OF TIME IS ALSO DEPENDENT ON THE AMOUNT OF RESOURCES AVAILABLE TO THE PROJECT AT EACH INSTANT OF TIME.

SINCE RESOURCES MAY DEFINITELY GOVERN PROJECT PROGRESS, THE FOLLOWING ADDITIONS TO THE CRITICAL PATH MODEL WOULD ENABLE A SCHEDULE WHICH CONSIDERS RESOURCES TO BE DEVELOPED

- PERFORM THE NORMAL CRITICAL PATH ANALYSIS IGNORING RESOURCES

- FOR EACH JOB DEFINE THE QUANTITY OF EVERY INDIVIDUAL RESOURCE REQUIRED TO EXECUTE THE JOB IN ITS ESTIMATED TIME

- SINCE THE PROJECT LENGTH IS NOW KNOWN, STATE THE TOTAL QUANTITY OF EACH INDIVIDUAL RESOURCE AVAILABLE DURING THE PROJECT DURATION

- CONSIDERING JOB SEQUENCE RELATIONSHIPS AND ESTIMATED JOB LENGTHS DEVELOP A MINIMUM FEASIBLE PROJECT SCHEDULE SUCH THAT THE AMOUNTS OF EACH INDIVIDUAL RESOURCE EMPLOYED BY THE JOBS IN PROGRESS AT ANY INSTANT DO NOT EXCEED THE AMOUNTS OF THAT RESOURCE AVAILABLE TO THE PROJECT.

SUCH A MODEL IS LIMITED IN THAT IT WOULD ASSUME THE INSTANTANEOUS SHIFTING OF RESOURCES FROM JOB TO JOB AND WOULD NOT CONSIDER THE ALLOCATION OF RESOURCES TO SEVERAL CONCURRENT DIFFERENT PROJECTS WHICH MIGHT EVEN BE GEOGRAPHICALLY APART.

THE NEGLECTING OF RESOURCES BY CRITICAL PATH ANALYSIS MAY NOT BE A SET BACK TO USERS OF THE TECHNIQUE. MANY PROJECTS WHICH WARRANT THE ANALYSIS ARE UNLIMITED SUCH THAT ANY NUMBER OF RESOURCES MAY BE APPLIED TO JOBS IN PROGRESS AT A GIVEN INSTANT. ALSO, THE ABILITY TO TAKE ADVANTAGE OF JOB FLOAT TIME DECREASES THE LIKELIHOOD THAT A PROJECT WILL BE SEVERELY RESOURCE RESTRICTED.

COMPUTER PROGRAMS HAVE BEEN WRITTEN TO AID IN RESOURCE ALLOCATION. ONE SUCH PROGRAM ACCOMODATES TEN WORK CLASSIFICATIONS WHICH THE JOBS IN THE PROJECT MAY UTILIZE AND CONSIDERS THE AVAILABILITY OF THE VARIOUS RESOURCES IN ARRIVING AT THE FASTEST SCHEDULE OF JOBS. IT ALLOCATES RESOURCES TO JOBS BASED UPON TOTAL FLOAT PRIORITY AND RELEASES RESOURCES FROM NON-CRITICAL JOBS TO CRITICAL JOBS SO THAT THE LATTER MAY START. NO JOB IS PERMITTED TO START IF THERE IS A PRECEDING JOB WITH HIGHER TOTAL FLOAT PRIORITY REQUIRING THE SAME AVAILABLE RESOURCE.

COMPUTER PROGRAMS USE THE OUTPUT FROM A PERT SCHEDULING PASS TO DEVISE A SCHEDULE FOR A PROJECT FOR WHICH THE RESOURCES ARE NOT INFINITE. THE RESULTING SCHEDULE WILL BE A FEASIBLE SCHEDULE BUT IT WILL NOT NECESSARILY BE AN OPTIMUM SCHEDULE. THAT IS, THERE MIGHT BE ANOTHER SCHEDULE WHICH WILL COMPLETE THE PROJECT IN A SHORTER PERIOD OF TIME THAN THAT DERIVED BY THE RESOURCE SCHEDULING PROGRAM. THE REASON THAT AN OPTIMAL SCHEDULE MIGHT NOT BE DEVELOPED IS BECAUSE A DECISION MADE IN TIME M WILL AFFECT THE CONDITIONS AND DECISIONS 1, 10, OR HUNDREDS OF PERIODS AWAY. A DECISION MAY BE OPTIMAL IN PERIOD M, BUT WILL BE VERY DETRIMENTAL TO PERIODS IN THE FUTURE. THE MEMORY SIZE AND/OR COMPUTER SPEED NECESSARY TO FIND AN OPTIMAL SOLUTION WITH TECHNIQUES WHICH SEEM TO EXIST TODAY ARE TOO OVERWHELMING TO IMPLEMENT IN THE COMPUTERS OF TODAY.

OFTEN THE RESOURCE AVAILABILITIES FOR A PROJECT ARE UNKNOWN BEFORE THE PROJECT BEGINS. IT IS IN THIS SITUATION THAT A RESOURCE SCHEDULING PROGRAM CAN SERVE A DUAL PURPOSE. FIRST, A SCHEDULE OF JOBS OF THE PROJECT IS CONSTRUCTED, SCHEDULING ALSO THE RESOURCES. SECONDLY, THE USER CAN CHOOSE ECONOMICAL RESOURCE QUANTITIES. IN ORDER TO CHOOSE ECONOMICAL RESOURCE QUANTITIES, THE USER MUST MAKE SEVERAL RUNS. DURING EACH RUN THE RESOURCE AVAILABILITIES ARE VARIED. THE USER CAN THEN INVESTIGATE WHAT EFFECT ON THE DURATION OF THE PROJECT VARIOUS COMBINATIONS OF RESOURCE AVAILABILITIES HAS.

RESOURCE ALLOCATION APPEARS TO HAVE VALUE FOR MULTI-JOB SCHEDULING WHERE MORE THAN ONE PROJECT DRAWS ON THE SAME RESOURCES. IF THE JOBS ARE ON THE SAME TIME SCALE, THEY MAY BE PROCESSED THROUGH THE SYSTEM AS ONE PROJECT. THE RESULTING SCHEDULE WILL MERGE THE JOBS WITHOUT DESTROYING THE LOGIC OF ANY ONE OF THE JOBS. AN EFFECTIVE WAY TO GIVE PRIORITY ON ONE PROJECT OVER ANOTHER HAS TO BE FOUND.

IN MANY PROJECTS THERE ARE STRINGS OF JOBS THAT IT IS DESIRABLE TO KEEP TOGETHER. NORMALLY, THERE IS NO WAY TO INDICATE THAT A JOB IS TO BE STARTED AS SOON AS THE PREVIOUS JOB IS COMPLETE. BY SETTING THE TOTAL FLOAT TIME TO ZERO FOR ALL BUT THE FIRST JOB IN THE STRING, THE JOBS WILL BE KEPT TOGETHER.

INTRODUCTION TO NETWORK RESOURCES

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THERE ARE SEVERAL TYPES OF RESOURCES THAT HAVE TO BE CONSIDERED IN A PROJECT. FOR EXAMPLE THERE ARE

- ◻ TIME RESOURCES
- ◻ LABOR RESOURCES
- ◻ EQUIPMENT RESOURCES
- ◻ COST RESOURCES

EVERY ACTIVITY HAS A TIME OR DURATION ASSOCIATED WITH IT. SOME ACTIVITIES MAY HAVE LABOR RESOURCES. CHANGES IN LABOR RESOURCES BETWEEN ONE SHIFT AND THE NEXT SHIFT SHOULD BE DESIGNATED BY DIFFERENT LABOR CATEGORIES OR CRAFTS. IF AN OPERATION REQUIRED ASSEMBLERS AND TEST TECHNICIANS, THE FOLLOWING DESIGNATIONS WOULD DESCRIBE THE SITUATION

1. FIRST SHIFT ASSEMBLERS-CATEGORY 1
2. FIRST SHIFT TEST TECHNICIANS-CATEGORY 2
3. SECOND SHIFT ASSEMBLERS-CATEGORY 3
4. SECOND SHIFT TECHNICIANS-CATEGORY 4

CERTAIN COMPUTER PROGRAMS ENABLE THE USER TO ALTER THE LABOR AND OTHER RESOURCES AT A PARTICULAR POINT IN TIME FOR A SPECIFIED DURATION OF TIME.

WHEN ASSIGNING RESOURCES TO AN ACTIVITY, IT IS IMPORTANT TO NOTE THAT ONLY THOSE CRAFTS WHICH MUST WORK TOGETHER SHOULD BE ASSIGNED TO THE SAME ACTIVITY. IF ALL LABOR CATEGORIES ARE NOT REQUIRED FOR THE ENTIRE DURATION OF AN ACTIVITY, THOSE CRAFTS WHICH ARE REQUIRED FOR LESS THAN THE TOTAL ACTIVITY DURATION SHOULD BE SHOWN ON A SEPARATE ACTIVITY. ALL ACTIVITIES FOR THIS GIVEN CONDITION WOULD BE IDENTICALLY DEFINED.

EFFECTIVE LEVELING AND BALANCING OF MANPOWER AND RESOURCES AGAINST A GIVEN SCHEDULE CAN BE DONE IN A SIMPLE MANNER. THE FIRST STEP IN THE LEVELING COMPUTATION IS TO SCHEDULE JOBS FALLING ALONG THE CRITICAL PATH AND TO COMPUTE BY CRAFT THE MANPOWER REQUIRED TO PERFORM THESE TASKS. THE NEXT STEP IS TO SCHEDULE EVERY JOB AT ITS EARLEST START DATE AND SUM EACH CRAFT FROM START TO FINISH TIME OF THE PROJECT. IN MOST CASES, THE SUMMATION WILL RESULT IN AN ERRATIC OR UNLEVELED MANPOWER SCHEDULE. HOWEVER, BY DISPLACING JOBS THAT HAVE FLOAT, A LEVELED CRAFT AND TOTAL FORCE CURVE CAN BE ARRIVED AT. IF CRAFT MANPOWER NEEDS EXCEED THOSE AVAILABLE FOR THE PROJECT, THEN A SCHEDULE WITH A LONGER DURATION WILL HAVE TO BE ADOPTED. LEVELING WILL ESTABLISH A STABLE CRAFT FORCE WHICH WILL WORK WITH HIGHER EFFICIENCY AND MORALE AND PRODUCE TANGIBLE RESULTS IN SAVINGS OF COSTS. IN ADDITION, SUPPORTING PERSONNEL SUCH A SUPERVISORS, SERVICE CRAFTS, AND ACCOUNTING CAN BE HELD TO A MINIMUM. TOOLS AND EQUIPMENT REQUIRED FOR THE PROJECT CAN ALSO BE KEPT AT A CONSTANT LEVEL. THE LEVELING AND BALANCING TECHNIQUE, IN SHORT, FORCES MANAGEMENT TO MAKE A SERIES OF DECISIONS THAT PREVIOUSLY MAY NOT HAVE BEEN CONSIDERED.

RESOURCE SCHEDULING CALCULATIONS

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THE CRITICAL PATH OUTPUT SHOWS HOW THE PROJECT COULD BE ACCOMPLISHED IN THE SHORTEST PERIOD OF TIME IF THERE WERE NO LABOR OR EQUIPMENT RESOURCE RESTRAINTS. THE RESOURCE ALLOCATIONS PROGRAMS MAKE THE FOLLOWING DECISIONS

1. WHEN THERE ARE SUFFICIENT LABOR RESOURCES TO START EACH ACTIVITY.

2. WHEN ACTIVITIES WHICH HAVE BEEN STARTED MUST BE DELAYED DUE TO RESOURCES BEING USED ON THE PARTICULAR ACTIVITY ARE NEEDED MORE URGENTLY ON ANOTHER ACTIVITY.

3. WHEN EACH ACTIVITY MUST BE FINISHED IN ORDER TO COMPLETE THE PROJECT ON TIME.

THE PROJECT DURATION, AS A RESULT OF THE RESOURCE CALCULATIONS, IS EQUAL TO OR GREATER THAN THE CRITICAL PATH DURATION. A RESOURCE SCHEDULE DURATION, WHICH IS LONGER THAN THE CRITICAL PATH DURATION, MEANS THAT CERTAIN ACTIVITIES WERE DELAYED IN STARTING BEYOND THEIR LATEST START TIME.

THE RESOURCE ALLOCATION PROGRAM IS AN EXTREMELY VALUABLE TOOL FOR DECISION MAKING. WITH IT IT IS POSSIBLE TO SIMULATE A PROJECT WITH VARIOUS LEVELS OF RESOURCES TO DETERMINE THEIR EFFECT ON THE TOTAL PROJECT DURATION. MANAGEMENT MAY EVALUATE SEVERAL OPERATING PLANS TO DETERMINE WHICH PLAN BEST FITS THE OBJECTIVES THEY HAVE OUTLINED FOR THE PROJECT. OPERATION PERSONNEL FIND THE RESOURCE SCHEDULE VERY EASY TO UNDERSTAND AND FOLLOW.

PROBLEM 13.

DRAW ARROW DIAGRAM. CALCULATE ES, LS, EF, LF, TF, FF.
DETERMINE CRITICAL PATH.

MARKETING OF INVENTION EXAMPLE

ACTIVITY AND RESOURCE LIST

I-J	DUR	ACTIVITY	CRAFT 1	CRAFT 2	CRAFT 3
1-2	10	BUDGET APPROVAL	0	0	0
2-3	15	PATENT CLEARANCE	9	0	0
2-4	5	FRAME ASSEMBLY PRINTS	0	20	0
2-5	20	SUB ASSEMBLY PRINTS	0	18	0
3-6	5	MARKETING PLAN APPROVAL	10	0	0
3-7	0	RESTRAINT LINE	0	0	0
4-8	10	FINAL ASSEMBLY	0	0	27
5-7	5	SUB ASSEMBLY	0	0	30
6-9	10	EDUCATION COURSE OUTLINES	8	0	0
6-10	5	PRODUCT MANUAL	10	20	30
7-8	15	SUB ASSEMBLY INTO FRAME	5	0	5
8-11	5	COVERS ASSEMBLY	0	10	0
9-10	25	TRAINING CLASSES	5	5	10
10-11	5	MAINTENANCE PROCEDURES	10	10	10
10-12	5	PREANNOUNCEMENT PLANS	0	5	0
11-12	10	PRODUCT RELIABILITY TEST	0	0	15

PROBLEM 13. SOLUTION

MARKETING OF INVENTION EXAMPLE

I-J	DUR	ACTIVITY	ES	LS	EF	LF	TF
1-2	10	BUDGET APPROVAL	0	0	10	10	0
2-3	15	PATENT CLEARANCE	10	10	25	25	0
3-6	5	MARKETING PLAN APPROVAL	25	25	30	30	0
6-9	10	EDUCATION OUTLINES	30	30	40	40	0
9-10	25	TRAINING CLASSES	40	40	65	65	0
10-11	5	MAINTENANCE PROCEDURE	65	65	70	70	0
11-12	10	PRODUCE RELIABILITY TEST	70	70	80	80	0
10-12	5	PRE-ANNOUNCEMENT PLANS	65	75	70	80	10
2-5	20	SUB ASSEMBLY PRINTS	10	25	30	45	15
5-7	5	SUB ASSEMBLY	30	45	35	50	15
7-8	15	SUB ASSEMBLY INTO FRAME	35	50	50	65	15
8-11	5	COVERS ASSEMBLY	50	65	55	70	15
3-7	0	RESTRAINT LINE	25	50	25	50	25
6-10	5	PRODUCT PUBLICATION MANUALS	30	60	35	65	30
2-4	5	FRAME ASSEMBLY PRINTS	10	50	15	55	40
4-8	10	FINAL ASSEMBLY	15	55	25	65	40

PROBLEM 14.

USING THE RESOURCE LIST OF PROBLEM 13. AND THE SOLUTION, DETERMINE THE CRAFT REQUIREMENTS BY TIME PERIODS. START EACH ACTIVITY BY ITS ES TIME. DETERMINE IF THE SCHEDULE IS DELAYED.

```
PROBLEM 14.  SOLUTION


MARKETING OF INVENTION EXAMPLE

RESOURCE ALLOCATION OUTPUT-MAXIMUM MANPOWER

DAY  ACTIVITY    STATUS   CRAFT 1   CRAFT 2   CRAFT 3
***  *******     ******   *******   *******   *******
  0     1-2      START        0         0         0
 10     1-2      FINISH       0         0         0
 10     2-3      START        9         0         0
 10     2-5      START        9        18         0
 10     2-4      START        9        38         0
 15     2-4      FINISH       9        18         0
 15     4-8      START        9        18        27
 25     2-3      FINISH       0        18        27
 25     4-8      FINISH       0        18         0
 25     3-6      START       10        18         0
 25     3-7      START       10        18         0
 25     3-7      FINISH      10        18         0
 30     3-6      FINISH       0         0         0
 30     6-9      START        8         0         0
 30     5-7      START        8         0        30
 30     6-10     START       18        20        60
 35     5-7      FINISH      18        20        30
 35     6-10     FINISH       8         0         0
 35     7-8      START       13         0         5
 40     6-9      FINISH       5         0         5
 40     9-10     START       10         5        15
 50     7-8      FINISH       5         5        10
 50     8-11     START        5        15        10
 55     8-11     FINISH       5         5        10
 65     9-10     FINISH       0         0         0
 65    10-11     START       10        10        10
 65    10-12     START       10        15        10
 70    10-11     FINISH       0         5         0
 70    10-12     FINISH       0         0         0
 70    11-12     START        0         0        15
 80    11-12     FINISH       0         0         0

TOTAL MAXIMUM RESOURCES      99        99        99
AVAILABLE TO COMPUTER

MAXIMUM MANPOWER REQUIRED    10        20        30
BY AN ACTIVITY

NOTE...THE THREE RESOURCE USED COLUMNS CONTAIN A
READOUT OF THE LABOR RESOURCES IN USE AT THE INSTANT
AN ACTIVITY WAS STARTED, DELEAYED OR FINISHED.
```

PROBLEM 15.

RE-DO PROBLEM 14. BUT ASSUME A RESOURCE LIMITATION OF 10 FOR CRAFT 1, 20 FOR CRAFT 2 AND 30 FOR CRAFT 3. DETERMINE IF THE SCHEDULE IS DELAYED.

PROBLEM 15. SOLUTION

MARKETING OF INVENTION EXAMPLE

RESOURCE ALLOCATION OUTPUT-MINIMUM MANPOWER

```
DAY  ACTIVITY     STATUS   CRAFT 1   CRAFT 2   CRAFT 3
***  *******      ******   *******   *******   *******
  0    1-2        START       0         0         0
 10    1-2        FINISH      0         0         0
 10    2-3        START       9         0         0
 10    2-5        START       9        18         0
 25    2-3        FINISH      0        18         0
 25    3-6        START      10        18         0
 25    3-7        START      10        18         0
 25    3-7        FINISH     10        18         0
 30    6-9        START       8         0         0
 30    2-4        START       8        20         0
 30    2-5        FINISH     10         0         0
 30    2-6        FINISH      0         0         0
 30    5-7        START       8        20        30
 35    2-4        FINISH      8         0        30
 35    5-7        FINISH      8         0         0
 35    4-8        START       8         0        27
 40    4-8        DELAY       0         0         0
 40    6-9        FINISH      0         0        27
 40    9-10       START       5         5        10
 40    7-8        START      10         5        15
 55    7-8        FINISH      5         5        10
 65    9-10       FINISH      0         0         0
 65    6-10       START      10        20        30
 70    6-10       FINISH      0         0         0
 70    4-8        START       0         0        27
 70   10-12       START       0         5        27
 75    4-8        FINISH      0         5         0
 75    8-11       START       0        15         0
 75   10-11       START      10        20        10
 75   10-12       DELAY       0        10         0
 80    8-11       FINISH     10        10        10
 80   10-11       FINISH      0         5         0
 80   10-12       START      10        15        10
 80   11-12       START       0         5        15
 80   10-12       FINISH      0         0        15
 90   11-12       FINISH      0         0         0

TOTAL MAXIMUM RESOURCES      10        20        30
AVAILABLE TO COMPUTER

MAXIMUM MANPOWER REQUIRED    10        20        30
BY AN ACTIVITY

NOTE...THE THREE RESOURCE USED COLUMNS CONTAIN A
READOUT OF THE LABOR RESOURCES IN USE AT THE INSTANT
AN ACTIVITY WAS STARTED, DELAYED OR FINISHED.
```

MARKETING OF INVENTION EXAMPLE-MAXIMUM MANPOWER

THE RESOURCE SCHEDULE OF PROBLEM 14 WAS COMPUTED WITH SUFFICIENT MANPOWER TO START EVERY ACTIVITY AT ITS EARLIEST START TIME. NO ACTIVITY WAS HELD UP FROM STARTING AND THEREFORE NO TOTAL FLOAT WAS USED UP BY THE COMPUTER. THE PROJECT WAS COMPLETED IN THE CRITICAL PATH TIME OF 80 DAYS. UNTIL AN ACTIVITY IS DELAYED FOR A NUMBER OF DAYS GREATER THAN ITS TOTAL FLOAT, IT WILL ALWAYS BE COMPLETED WITH 80 DAYS. IF THE TOTAL RESOURCES IN CRAFT 2 WERE REDUCED FROM 31 TO 29 THE PROJECT DURATION WOULD BE EXTENDED TO 85 DAYS.

MARKETING OF INVENTION EXAMPLE-MINIMUM MANPOWER

THE RESOURCE SCHEDULE OF PROBLEM 15 WAS COMPLETED WITH THE MINIMUM NUMBER OF MEN IN EACH LABOR CRAFT. RESOURCES CAN NEVER BE LESS THAN THAT REQUIRED BY ANY ONE ACTIVITY. THIS SCHEDULE CONTAINS TWO DELAYS. A DELAY RESULTS FROM AN ACTIVIY IN PROCESS WHICH HAS MORE FLOAT IN IT THAN AN ACTIVITY WHICH IS READY TO START. ACTIVITY 4-8 HAD AN EARLIEST START TIME OF DAY 15. IT WAS ACTUALLY STARTED ON DAY 35. IT WAS DELAYED 20 DAYS. IT STARTED WITH 20 DAYS TOTAL FLOAT. ON DAY 40 ACTIVITY 9-10 WITH ZERO TOTAL FLOAT AND AN EARLIEST START TIME OF 40 WAS READY TO START. ON DAY 40 THERE WERE 8 MEN IN USE IN CRAFT 1 AND 27 MEN IN CRAFT 3. AT THE START OF DAY 40 THERE REMAINED 2 MEN IN CRAFT 1, 20 MEN IN CRAFT 2, AND 3 MEN IN CRAFT 3 NOT IN USE. THESE RESOURCES DID NOT SATISFY THE REQUIREMENTS OF ACTIVITY 9-10. THE COMPUTER THEREFORE SEARCHED THE IN PROCESS ACTIVITIES TO DETERMINE WHICH ACTIVITIES WERE USING THE SAME CRAFTS THAT ACTIVITY 9-10 NEEDED. OF THE ACTIVITIES FOUND THE ONE WITH THE LARGEST AMOUNT OF TOTAL FLOAT WAS SELECTED TO BE DELAYED. ACTIVITY 4-8 HAD THE LARGEST AMOUNT OF TOTAL FLOAT. IT WAS DELAYED ON DAY 40 AND 27 MORE MEN WERE AVAILABLE FOR OTHER ACTIVITIES. ACTIVITY 9-10 AND 7-8 STARTED ON DAY 40. BY DAY 60 ACTIVITY 4-8 HAD ZERO TOTAL FLOAT. IT WAS NOT UNTIL DAY 70 THAT SUFFICIENT RESOURCES WERE AVAILABLE TO RESTART ACTIVITY 4-8. THERE WERE NO ACTIVITIES WHICH COULD BE DELAYED BETWEEN DAYS 60 AND 70 SINCE THE ACTIVITIES IN PROCESS HAD LESS ORIGINAL TOTAL FLOAT THAN ACTIVITY 4-8. THE ACTIVITY FINALLY FINISHED UP ON DAY 75. THIS IS AN EXAMPLE OF HOW A COMPUTER CAN PERFORM THE RESOURCE ALLOCATION CALCULATIONS.

RESOURCE SCHEDULING SIMULATION
****

SAMPLE PROBLEM 16 CONTAINS 9 MANPOWER SIMULATIONS PERFORMED ON THE MARKETING OF INVENTION NETWORK. THE PURPOSE OF THESE SIMULATIONS WAS TO DETERMINE AT WHAT POINT THE PROJECT DURATION WAS EXTENDED. IN PREPARING ALTERNATIVES FOR MANAGEMENTS EVALUATION, SIMULATIONS 3,5, AND 9 WOULD HAVE BEEN SELECTED FOR PRESENTATION. THESE THREE LEVELS OF RESOURCES REPRESENT THE MANPOWER REQUIRED FOR COMPLETION OF THE PROJECT FROM MINIMUM TO MAXIMUM DURATION.

IT SHOULD BE NOTED THAT AS THE DURATION OF A PROJECT BECOMES LONGER THAT DELAYS ARE NOT NECESSARILY PRESENT IN THE SCHEDULE. THE OUTPUT FROM EACH SIMULATION SHOULD BE CAREFULLY STUDIED BEFORE ANOTHER SIMULATION IS PERFORMED. IN A REAL LIFE SITUATION THE SIMULATION WOULD HAVE BEEN STOPPED WITH NUMBER 6. THIS IS THE POINT AT WHICH THE COMPUTER RESOURCES EQUAL THE LARGEST NUMBER OF MEN REQUIRED BY ANY ONE ACTIVITY.

A STUDY OF EACH RESOURCE SCHEDULE PRODUCED BY THE COMPUTER WILL SHOW HOW MANY RESOURCES ARE IN USE AT ANY ONE POINT IN TIME. IF THIS RESOURCE UTILIZATION WAS PLOTTED WITH THE DURATION ON THE X-AXIS, AND THE NUMBER OF MEN IN USE ON THE Y-AXIS, IT WOULD BE FOUND THAT AS THE RESOURCES ARE DECREASED A MORE CONSTANT UTILIZATION OF RESOURCES TAKES PLACE. THE ADVANTAGES OF A CONSTANT LABOR REQUIREMENT ARE SELF EVIDENT. PLOTTING THE RESOURCE SCHEDULE UTILIZATION WILL HIGHLIGHT POINTS IN THE NETWORK WHERE REPLANNING AND REALLOCATION OF RESOURCES MAY BE DESIRABLE. FREQUENTLY, REPLANNING AFTER STUDYING THE RESOURCE SCHEDULE OUTPUT WILL REDUCE THE PROJECT DURATION AND DECREASE THE MANPOWER REQUIREMENTS.

SAMPLE PROBLEM 16

MARKETING OF INVENTION EXAMPLE

SIMULATION OF RESOURCE LEVELS

```
*--*---------*------*---------*------*---------*------*--------*------*
   *    CRAFT 1     *    CRAFT 2     *    CRAFT 3     * PROJECT*NUMBER*
*# *PROJECTED*ACTUAL*PROJECTED*ACTUAL*PROJECTED*ACTUAL*DURATION*DELAYS*
*--*---------*------*---------*------*---------*------*--------*------*
*1 *   99    *  18  *   99    *  38  *   99    *  60  *   80   *   0  *
*--*---------*------*---------*------*---------*------*--------*------*
*2 *   16    *  15  *   33    *  25  *   53    *  42  *   80   *   0  *
*--*---------*------*---------*------*---------*------*--------*------*
*3 *   15    *  13  *   31    *  25  *   49    *  42  *   80   *   0  *
*--*---------*------*---------*------*---------*------*--------*------*
*4 *   14    *  13  *   29    *  20  *   45    *  42  *   85   *   0  *
*--*---------*------*---------*------*---------*------*--------*------*
*5 *   12    *  10  *   20    *  20  *   37    *  37  *   85   *   0  *
*--*---------*------*---------*------*---------*------*--------*------*
*6 *   11    *  10  *   20    *  20  *   36    *  30  *   90   *   2  *
*--*---------*------*---------*------*---------*------*--------*------*
*7 *   10    *  10  *   20    *  20  *   35    *  30  *   90   *   2  *
*--*---------*------*---------*------*---------*------*--------*------*
*8 *   10    *  10  *   20    *  20  *   33    *  30  *   90   *   2  *
*--*---------*------*---------*------*---------*------*--------*------*
*9 *   10    *  10  *   20    *  20  *   30    *  30  *   90   *   2  *
*--*---------*------*---------*------*---------*------*--------*------*
```

PROJECTED IS THAT QUANTITY OF RESOURCES GIVEN TO THE COMPUTER
WITH WHICH TO SCHEDULE THE PROJECT.

ACTUAL IS THE LARGEST NUMBER OF MEN THE COMPUTER USED AT ANY ONE
TIME WHILE IT WAS SCHEDULING THE PROJECT.

NETWORK MAINTENANCE
****

CHANGES ARE EASILY MADE IN A PERT NETWORK. MAINTENANCE OF A NETWORK IS AN IMPORTANT FACTOR IN THE SUCCESSFUL OPERATION OF THE PERT PROJECT MANAGEMENT SYSTEM.

THE FOLLOWING QUESTIONS SHOULD BE ASKED WHEN UPDATING A NETWORK

1. WHAT NEW INFORMATION CAN BE REFLECTED IN THE NETWORK. THIS NEW INFORMATION MAY BE IN THE NATURE OF REVISED LABOR RESORUCE ESTIMATES OR TIME ESTIMATES.

2. WHAT ACTIVITIES ARE IN-PROCESS. HOW MANY DAYS OF WORK REMAIN TO BE ACCOMPLISHED BEFORE THE ACTIVITY CAN BE CONSIDERED COMPLETE.

3. WHAT ACTIVITIES HAVE BEEN COMPLETED.

THE FREQUENCY WITH WHICH A PERT NETWORK IS UPDATED IS VARIABLE. ONE OF THE MOST IMPORTANT FEATURES OF THE PERT SYSTEM IS THAT IT PROVIDES MANAGEMENT WITH A CURRENT DYNAMIC ANALYSIS OF A PROJECT. REVISED DATA MUST THEREFORE BE CONSTANTLY FED INTO THE NETWORK. THE EXACT METHOD BY WHICH A NETWORK IS UPDATED WILL DEPEND UPON THE NATURE OF THE PROJECT. SOME FIRMS FIND PERIODIC MEETINGS A SATISFACTORY METHOD OF MAINTAINING A NETWORK. SOME FIND PRE-PUNCHED CARDS USEFUL.

THE FIRST ACTIVITY IS USUALLY THE SHOP DATE OR AN ACTIVITY TO PLACE THE NETWORK ON A CURRENT CALENDAR BASIS. EACH TIME A NETWORK IS CALCULATED, THIS CARD IS CHANGED TO REFLECT THE CURRENT SHOP DATE. AS ACTIVITIES ARE COMPLETED, THEY SHOULD BE REMOVED FROM THE PERT INPUT DECK. THIS WILL REDUCE THE NUMBER OF ACTIVITIES THAT THE COMPUTER MUST CALCULATE. COMPUTER TIME IS REDUCED AS THE PROJECT PROGRESSES TOWARDS COMPLETION. ACTIVITIES WHICH ARE REMOVED FROM A NETWORK MAKE THE NETWORK INCOMPLETE. THIS CONDITION IS CORRECTED BY ADDING ZERO DURATION ACTIVITIES FROM THE BASE LINE TO THE I NODE OF THE DANGLING ACTIVITY. SEE FIGURE B8.

EACH TIME THE NETWORK IS UPDATED, THE PREVIOUS ZERO DURATION ACTIVITIES ARE REMOVED. THE COMPLETED ACTIVITIES ARE REMOVED AND THE NEW ZERO DURATION ACTIVITIES ARE INSERTED. THE NETWORK SHOULD THEN BE CHECKED FOR COMPLETENESS.

AFTER THE DESIRED MANPOWER RESOURCE LEVEL HAS BEEN DETERMINED AND THE PROJECT HAS ACTUALLY STARTED, IT IS NOT GENERALLY NECESSARY TO COMPUTE A COMPLETE MAN SCHEDULE EACH TIME THE NETWORK IS UPDATED. IF THE NETWORK IS UPDATED WEEKLY, A MAN SHCEDULE OF TWO WEEKS DURATION BEYOND THE BASE LINE IS GENERALLY SUFFICIENT FOR OPERATING PERSONNEL. A COMPLETE CRITICAL PATH CALCULATION SHOULD BE PERFORMED EACH TIME A NETWORK IS UPDATED.

SOURCE...REFERENCE 8

PROBLEM 17

RUN THE FOLLOWING ACTIVITY LIST ON THE COMPUTER.

ACTIVITY	I	J	ET
A	1	4	15
B	1	2	9
C	1	5	7
D	1	6	6
F	2	3	11
G	3	4	6
H	4	10	10
I	4	11	4
J	11	12	7
K	7	8	9
L	6	9	8
M	5	6	8
N	9	10	5
O	9	15	4
P	15	16	5
Q	16	17	9
R	12	14	6
S	8	10	4
T	10	13	5
U	13	14	8
V	14	17	12
W	3	7	5
X	5	7	6

PROBLEM 18

UPDATE THE NETWORK OF PROBLEM 17 BY UTILIZING THE FOLLOWING INFORMATION

COMPLETED ACTIVITIES A,B,C,D,F,G,I,L,M,W, AND X.

RESTIMATED ACTIVITES AND TIMES H-8, J-1, AND K-2.

ASSUME 32 CALENDAR DAYS HAVE BEEN USED ON THE PROJECT.

IMPLEMENTATION OF PERT

THE BASIC COMCEPT OF THE PERT APPROACH IS DECEIVINGLY SIMPLE. THIS CLARITY AND SIMPLICITY OBSCURES THE FACT THAT APPLICATION IN A REAL-LIFE SITUATION CAN BE COMPLEX. SOME IMPLEMENTATION CONSIDERATIONS ARE

PERT IS A MANAGEMENT RESPONSIBILITY

- MANAGEMENT MUST INVOLVE ITSELF CONSIDERABLY IN THE PERT APPLICATION AND OPERATION.
- PURPOSE OF PERT IS TO FURNISH IMPROVED MEANS TO MANAGE A PROJECT OR ENTERPRISE.
- ONLY MANAGEMENT KNOWS WHAT IS NEEDED TO BETTER MANAGE.
- PERT MAY REQUIRE MORE MANAGEMENT ATTENTION THAN TRIED TECHNIQUES.
- MANAGEMENT MUST DETERMINE THE FEASIBILITY OF PERT IN RELATION TO THEIR INFORMATION NEEDS.
- MANAGEMENT MUST CONTINUALLY MONITOR THE APPLICATION FOR USEFULNESS AND PRACTICALITY.

PERT IS NOT AN AUTOMATIC SYSTEM

- PERT IS NOT AN AUTOMATIC SYSTEM OR A SUBSTITUTE FOR MANAGEMENT DECISION.
- PERT IS SIMPLY A DEVICE FOR ACCUMULATING AND INTEGRATING CONSISTENT HUMAN JUDGMENTS AND PRESENTING THE RESULTS OF THIS INTEGRATION TO MANAGEMENT FOR THEIR FURTHER JUDGMENT.
- GOOD BENEFITS FROM PERT REQUIRE THAT USERS CONCERN THEMSELVES WITH SOURCE INPUTS, THEIR SIMPLICITY, THEIR FEASIBILITY, AND THEIR POSSIBLE ACCURACY.

PERT OFTEN CLASHES WITH TRADITIONAL ORGANIZATION PATTERNS

- PERT CUTS ACROSS FUNCTIONAL, ORGANIZATIONAL, AND COMPANY LINES.
- IT TREATS A PROJECT AS AN INTEGRATED PROGRAM AND THUS DEPARTS FROM TRADITIONAL, LONG-STANDING ORGANIZATIONAL PATTERNS.
- IT SPOTLIGHTS THE NONPERFORMER WHO FORMERLY WAS ABLE TO HIDE.
- PERT STIPULATES COORDINATION AND COOPERATION, CUTTING ACROSS LINES OF AUTHORITY .

LEARNING TO USE A DYNAMIC CONTROL SYSTEM

- AS INDIVIDUALS, EXECUTIVES, AND SUPERVISORS HAVE BEEN LONG TRAINED IN STATIC TECHNIQUES FOR PLANNING AND CONTROL INFORMATION REPORTING.
- THEIR FAMILIARITY WITH THESE TECHNIQUES IS GREAT, AND THEIR SUCCESS WITH THESE METHODS IS UNQUESTIONED.
- PERT WITH ITS OPPORTUNITY FOR DYNAMIC PLANNING AND CONTROL, ITS CONTINUAL PROBING OF THE FUTURE AND EVALUATION OF ALTERNATIVE COURSES OF ACTION, ITS FEEDBACK CYCLE, AND ITS CONSTANT CHANGE MAY CREATE A PROBLEM.

PERT MUST BE USED WITH OTHER MANAGEMENT SYSTEMS

- PERT MUST BE CONSIDERED IN ITS APPLICATION IN THE LIGHT OF OTHER EXISTING MANAGEMENT PROCEDURES AND SYSTEMS.
- PERT MUST BE SO INSTALLED THAT IT MAKES FULL USE OF THE INPUTS AND CROSS-OVERS FROM THESE OTHER SYSTEMS, AND SO THAT ITS OUTPUT MAY BE INTERPRETED IN RELATION TO THE OUTPUTS OF THESE OTHER SYSTEMS TO MANAGEMENT.
- PERT IS NOT A SUBSTITUTE FOR ALL MANAGEMENT SYSTEMS NOR ARE ITS REQUIREMENTS SO INFLEXIBLE THAT OTHER MANAGEMENT SYSTEMS MUST BEND TO MEET ITS REQUIREMENTS.
- PERT ITSELF IS FLEXIBLE AND BOTH CAN AND SHOULD BE ADAPTED TO THE SPECIFIC MANAGEMENT SITUATION INTO WHICH IT IS INTRODUCED.

PERT CANNOT BE A RIGIDLY STANDARDIZED TECHNIQUE

- PERT IS A GENERALIZED TECHNIQUE AND HAS A CONSISTENT PATTERN THAT CAN AND SHOULD BE FLEXIBLY ADAPTED TO SPECIFIC NEEDS.
- PERT IS NOT A RIGID PROCEDURE THAT CAN BE STANDARDIZED IN ALL DETAIL FOR ALL SITUATIONS.
- IN ANY ENTERPRISE, THE MAIN TASK IS TO MANAGE THAT COMPANY SO THAT THE OBJECTIVES PECULIAR AND UNIQUE TO THAT COMPANY ARE FULLY MET.
- EVERY MANAGEMENT TOOL MUST BE ADAPTED TO THIS CENTRAL REQUIREMENT.
- THE COMPANY CANNOT BE ADAPTED TO THE PROCEDURAL REQUIREMENTS OF THE MANAGEMENT TOOL.

SOURCE...REFERENCE 1

ORGANIZATION FOR EFFECTIVE USE OF PERT

IF PERT IS TO BE EFFECTIVE FOR MANAGEMENT PLANNING AND CONTROL, IT IS NECESSARY TO HAVE AN ORGANIZATION ORIENTED TO THE EFFICIENT USE OF THE TOOL, AND TO THE RAPID COLLECTION AND DISSEMINATION OF PERTINENT INFORMATION. IN THIS WAY THE FUNCTIONS OF PLANNING, SCHEDULING, CONTROL AND EVALUATION MAY BE EFFECTIVELY HANDLED. FIGURE D1 DISPLAYS A SAMPLE ORGANIZATIONAL STRUCTURE FOR EFFICIENTLY COORDINATING PROJECT ADMINISTRATION. THE EXACT LOCATION WITHIN AN ORGANIZATION OF THE VARIOUS FUNCTIONS MAY CHANGE ACCORDING TO THE SIZE OF THE COMPANY, THE SIZE OF THE PROJECT, OR SIMPLY THE NUMBER OF PEOPLE MADE AVAILABLE TO IMPLEMENT PERT. THE IMPORTANT CONCEPT TO NOTE IN FIGURE D1 IS THE CENTER BOX INDICATED AS PLANS, SCHEDULES, AND CONTROL. THIS IS A STAFF GROUP ORIENTED TO THE CONTROL OF AN ENTIRE PROJECT FROM START TO FINISH. ALL INFORMATION PASSES THROUGH THIS GROUP. THEY ARE RESPONSIBLE FOR

- DEVELOPING THE ORIGINAL NETWORK.
- DEVELOPING THE COMPUTER INPUT.
- INTERPRETING THE OUTPUT.
- PREPARING DETAILED INSTRUCTIONS FOR THE FIELD.
- EVALUATING FIELD WORK FOR MANAGEMENT IN A FORM WHICH CAN BE USED.
- REVIEWING THE STATUS OF THE PROJECT WITH MANAGEMENT.
- TRANSMITTING REVISED RESOURCE AND TIME SCHEDULES TO THE FIELD.

DEPENDING ON THE SIZE OF THE COMPANY, OR THE PROJECT, THIS GROUP MAY BE ONE MAN LOCATED AT THE PROJECT SITE OR IT MAY BE A DEPARTMENT OF MANY MEN LOCATED AT A CENTRAL OR REGIONAL OFFICE. THE EXACT FORM IN WHICH IT EXISTS MAY NOT BE IMPORTANT, BUT THE VERY EXISTENCE OF A SINGLE GROUP RESPONSIBLE FOR ALL ASPECTS OF A PROJECT IS IMPERATIVE.

THE QUALIFICATIONS FOR THE PEOPLE MAKING UP THIS GROUP ARE EXACTING. THEY MUST BE FAMILIAR WITH THE MEANS OF ACCOMPLISHING THE PROJECT AND THE TECHNIQUES FOR DEVELOPING NETWORK MODELS. THEY MUST BE ABLE TO COMMUNICATE WITH PROJECT PERSONNEL, COMPUTER AND TECHNICAL PERSONNEL, AND MANAGEMENT. THEY MUST BE ABLE TO INTERPRET PROJECT INFORMATION AND DISSEMINATE IT TO MANAGEMENT IN A FORM WHICH WILL ALLOW RAPID AND SUCCESSFUL DECISION MAKING.

ONE OF THE BENEFITS WHICH CAN BE DERIVED FROM THE PERT TECHNIQUE IS THE RAPID EXPEDITING OF CRITICAL ACTIVITIES WHILE AT THE SAME TIME AVOIDING COSTLY ACCELERATION OF ACTIVITIES WHICH ALTHOUGH BEHIND SCHEDULE DO NOT AFFECT THE PROJECT PERFORMANCE OR COMPLETION. THIS CAN BE ACCOMPLISHED ONLY IF THE INFORMATION AVAILABLE FROM THE JOB SITE IS TRANSFERRED RAPIDLY INTO A FORM SUITABLE FOR EVALUATION, AND IS THEN TRANSMITTED IMMEDIATELY TO MANAGEMENT. IF EXCESSIVE TIME IS LOST BETWEEN THE ORIGIN OF THE INFORMATION AT THE JOB SITE AND ITS PRESENTATION TO MANAGEMENT, THE EFFECTIVENESS OF THIS TOOL WILL BE LESSENED. THIS POINT MUST BE REMEMBERED IN DEVELOPING AN ORGANIZATION FOR PLANNING AND CONTROLLING PROJECTS. THE ORGANIZATION STRUCTURE

- SHOULD BE STREAMLINED.
- SHOULD HAVE SHORT LINES OF COMMUNICATION.
- SHOULD INCLUDE AUTOMATED PROCEDURES WHEREVER POSSIBLE.
- SHOULD HAVE RIGID FORMS FOR SUPPLYING AND DISSEMINATING INFORMATION.
- SHOULD HAVE ALL PEOPLE WITH THE ORGANIZATION BE THOROUGHLY FAMILIAR WITH THE TOOL WITH WHICH THEY ARE WORKING.

IF A SUCCESSFUL ORGANIZATION IS DEVELOPED AND THOROUGH KNOWLEDGE OF THE PROJECT AND THE TECHNIQUE IS AVAILABLE, THE NEXT BASIC PROBLEM IS THE FORM IN WHICH INFORMATION MAY BE TRANSFERRED INTERNALLY FOR THE EFFECTIVE COMPLETION OF THE PROJECT.

SOURCE...REFERENCE 9

INFORMATION DISPLAY FOR PLANNING, CONTROL, AND EVALUATION

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THE CLUE TO SUCCESSFUL INFORMATION DISPLAY COMES FROM THE MOST BASIC ELEMENT OF PERT, THE NETWORK. THIS PICTORIAL MODEL IS RECOGNIZED AS AN EFFECTIVE WAY OF DISPLAYING THE RELATIONSHIPS IN COMPLEX SITUATIONS. THE CONCEPT HERE IS THE RELIANCE ON A PICTORIAL MODEL. FOR THE SAME REASON REPORTING AND INFORMATION DISPLAY SHOULD BE ORIENTED TO PICTORIAL FORMS. THE GOAL IS TO DISPLAY THE MOST INFORMATION IN THE MOST USABLE FORM.

FIGURE D2 IS AN EXAMPLE OF NETWORK FORMAT FOR USE IN THE FIELD OR OFFICE FOR CONTROL PURPOSES. THIS NETWORK CLEARLY DISPLAYS THE HIERARCHY OF CRITICAL AND NEAR-CRITICAL PATHS. THE FACT THAT SEQUENCES OF ACTIVITIES CAN USUALLY BE IDENTIFIED WITHIN THE ENTIRE NETWORK ALLOWS THIS HIERARCHY TO BE DEVELOPED. THE PRIMARY REASON FOR USING THIS TECHNIQUE IS TO IDENTIFY CLEARLY THE ACTIVITIES WHICH AT ANY POINT IN TIME SHOULD BE RECEIVING THE MOST ATTENTION FROM MANAGEMENT AND PROJECT PERSONNEL. AS THE PROJECT PROGRESSES THE RELATIONSHIPS OF ACTIVITIES CHANGE DUE TO NATURAL EFFECTS, AND THE NETWORK BEING USED FOR CONTROL SHOULD BE UPDATED TO REFLECT THE CURRENT SITUATION.

FIGURE D3 IS A BAR GRAPH FOR DISPLAYING THE RESULTS OF THE CPM CALCULATIONS IN A FORM WHICH IS USEFUL FOR CONTROL BOTH IN THE OFFICE AND IN THE FIELD. THE BAR CHART DEFINES THE START AND FINISH OF ACTIVITIES AND THE FLOAT ASSOCIATED WITH EACH ACTIVITY. THE BAR CHART CLEARLY IDENTIFIES ACTIVITIES GOING ON AT THE SAME TIME, AND THE PRECEDENCE OF ACTIVITIES. IT IS MORE MANAGEABLE THAN THE STRAIGHT CPM NUMERICAL LISTING. THIS EASE OF INTERPRETATION PARTICULARLY AIDS THE PEOPLE WHO ARE RESPONSIBLE FOR COMPLETING THE PROJECT.

THE FIRST TWO STEPS OF PROJECT CONTROL HAVE NOW BEEN ACCOMPLISHED. THE NETWORK HAS BEEN INTERPRETED BY DELINEATING THE HIERARCHY OF CRITICAL AND NEAR-CRITICAL PATHS, AND A SCHEDULE FORMAT HAS BEEN DEVELOPED FOR THE USE OF PROJECT PERSONNEL. THE NEXT STEP IS TO DEVELOP A FORMAT FOR TRANSFERRING INFORMATION BACK TO THE CONTROL GROUP, AND THEN TO MANAGEMENT. THIS INFORMATION MUST REFLECT THE EXACT NATURE OF THE PROGRESS OF THE PROJECT. SUCH A REPORT SHOULD IDENTIFY CLEARLY AND CONCISELY

1. ALL ACTIVITIES WHICH HAVE BEEN COMPLETED ON OR BEFORE SCHEDULE AND THEIR RELATIONSHIP TO THE REMAINDER OF THE PROJECT.

2. ALL ACTIVITIES WHICH SHOULD BE COMPLETE AT THE TIME THE REPORT IS SUBMITTED, BUT AS YET ARE NOT COMPLETE, AND THE REASONS FOR THE DELAY.

3. THE STATUS OF ACTIVITIES WHICH ARE BEING PERFORMED AT THE TIME OF THE REPORT.

4. ALL KNOWN INFLUENCES WHICH WILL COME TO BEAR ON THE PROJECT DURING THE COMING REPORTING PERIOD. THIS INTELLIGENCE IS NECESSARY IF CORRECTIVE ACTION TAKEN BY MANAGEMENT IS TO BE IN HARMONY WITH THE PROJECT DEVELOPMENT.

THE DETAIL REQUIRED IN THE FORM ACTUALLY USED WILL DEPEND ON THE COMPLEXITY OF THE PROJECTS WHICH MUST BE UNDERTAKEN. IT IS ADVISABLE, HOWEVER, TO USE A SINGLE FORM FOR ALL PROJECTS. THE FORM SHOULD BE DEVELOPED FOR THE MOST COMPLEX PROJECT WHICH WILL BE ENCOUNTERED, AND

DESIGNED IN SUCH A WAY THAT IT MAY BE USED IN ABBREVIATED OR SIMPLIFIED FORM FOR LESS COMPLEX JOBS.

THERE ARE TWO BASIC FORMS WHICH MAY BE USED AND SEVERAL VARIETIES OF THESE. THE MOST STRAIGHTFORWARD IS THE NARRATIVE REPORT. IF THIS TYPE OF REPORT IS USED, IT IS ESSENTIAL THAT A DEFINITE FORMAT SUCH AS THAT SHOWN IN FIGURE D4 BE ESTABLISHED. AN EXAMPLE OF THE DESIRED FORMAT SHOULD BE PROVIDED FOR ALL PERSONNEL TO USE AS A GUIDE. IN MANY INSTANCES IT WILL BE BETTER TO REVERSE THE FORMAT SHOWN IN FIGURE D4, THUS PRESENTING THE MOST CRITICAL SITUATIONS FIRST AND FINISHING WITH THOSE WHICH ARE UNDER CONTROL. IN THIS WAY ATTENTION IS IMMEDIATELY DIRECTED TO THE AREAS WHERE CORRECTION BY MANAGEMENT IS REQUIRED. AS PROJECTS BECOME MORE COMPLEX IT IS ADVANTAGEOUS FOR THE REPORTING FORM TO RELATE DIRECTLY TO THE NETWORK DIAGRAM. AN EXAMPLE OF SUCH A FORM IS SHOWN IN FIGURE D5. IN EACH FORM THE FOLLOWING POINTS ARE SPECIFIED

1. EACH ACTIVITY IS IDENTIFIED BOTH BY NODE NUMBERS AND VERBAL DESCRIPTION.

2. PROVISION IS MADE FOR INDICATING SCHEDULED COMPLETION, ESTIMATED OR ACTUAL COMPLETION, AND THE AMOUNT OF FLOAT ASSOCIATED WITH THE ACTIVITY.

3. A VERBAL DESCRIPTION TO INDICATE THE NATURE OF ALL PROBLEMS AND SUCCESSES.

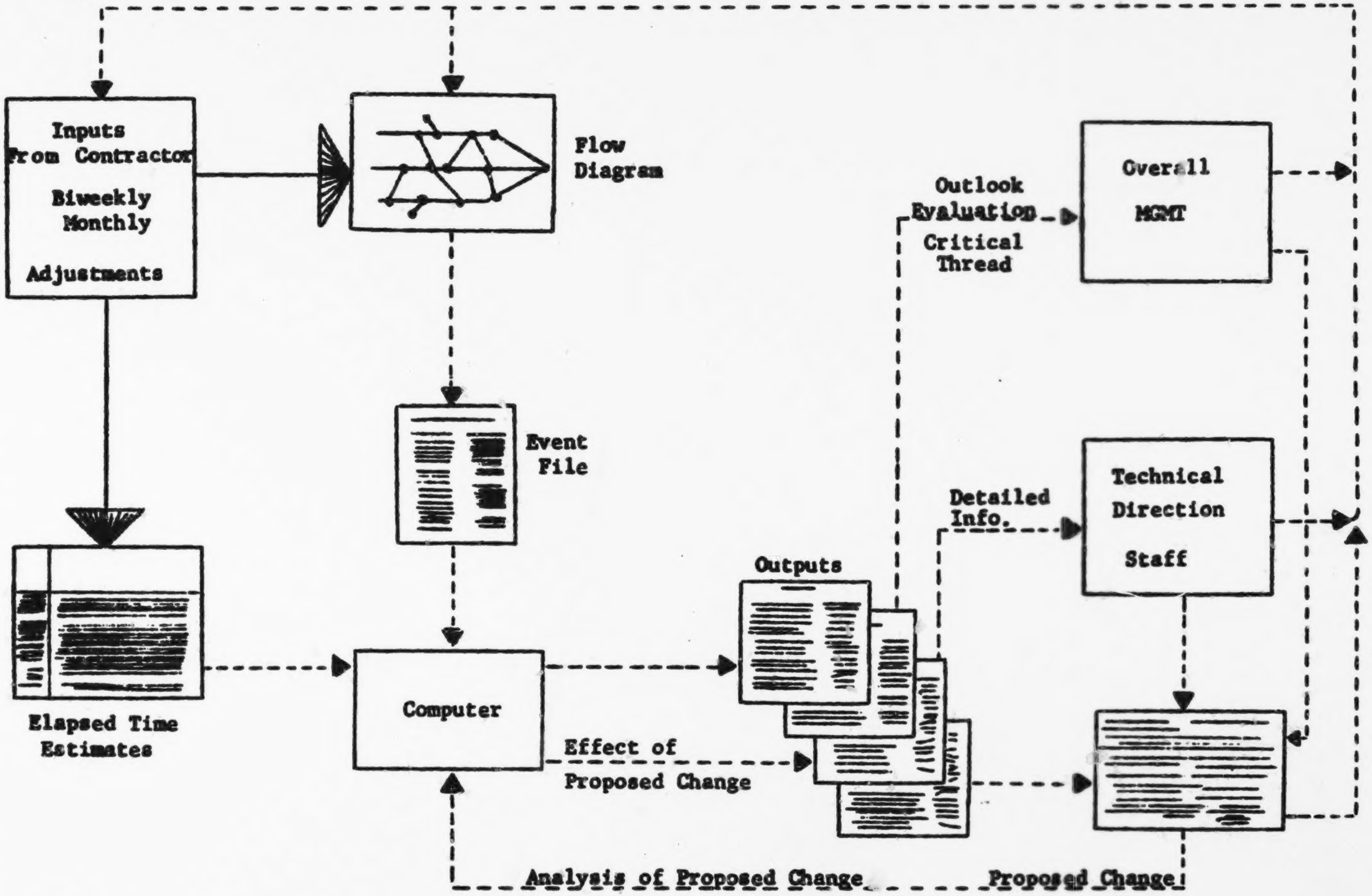
THERE ARE TWO WAYS OF DEVELOPING THESE REPORTS. IN THE FIRST, ACTIVITIES WHICH ARE TO BE REPORTED ARE SPECIFIED BY THE CONTROL GROUP, AND THEIR IDENTIFICATION IS PROVIDED ON THE REPORT AT THE TIME IT IS SENT TO THE FIELD. PROJECT PERSONNEL REPORT ON THE SPECIFIED ACTIVITIES, PLUS ANY THEY WISH TO ADD. THE OTHER APPROACH IS TO SEND A BLANK FORM TO THE FIELD AND ALLOW THE PROJECT PERSONNEL TO SUBMIT THE INFORMATION WHICH THEY FEEL IS PERTINENT. EACH TECHNIQUE HAS ITS ADVANTAGES DEPENDING ON THE SIZE OF THE PROJECT, THE CALIBER AND KNOWLEDGE OF THE PEOPLE PERFORMING THE PROJECT, AND THE MEANS OF COMMUNICATION USED BETWEEN THE VARIOUS PARTS OF THE ORGANIZATION.

WHEN THE COMPLETED FORM IS SUBMITTED TO THE CONTROL GROUP IT BECOMES THEIR RESPONSIBILITY TO INTERPRET THE FIELD REPORT, DEVELOP CORRECTIVE INFORMATION, AND TRANSFER THIS INFORMATION TO MANAGEMENT AND BACK TO THE FIELD IN FORMS USABLE BY EACH GROUP. USING THE FIELD REPORT, THE CONTROL GROUP REVISES THE NETWORK AND COMPUTATIONS TO REFLECT CURRENT PROJECT STATUS. NOW THEY MUST PROVIDE INFORMATION FOR THE CORRECT UTILIZATION OF THE INTELLIGENCE GATHERED FROM THE FIELD. FIGURE D2 PRESENTS A GENERAL FORMAT FOR EFFECTIVE INFORMATION DISPLAY FOR MANAGEMENT USE. THE TREND CHARTS AT THE BOTTOM OF THE PAGE INDICATE THE PERSISTENT NATURE OF THE PROJECT. ANY VARIABLE SUCH AS TIME, COST, OR RESOURCE USAGE WHICH IS BELIEVED TO REFLECT THE PROGRESS OF THE PROJECT MAY BE INCLUDED. THIS IS THE FIRST POINT OF REVIEW FOR MANAGEMENT, FOR HERE THEY CAN RECOGNIZE PROJECT TRENDS. IF ALL TRENDS SEEM TO BE OF A FAVORABLE NATURE, THE MANAGER MAY NOT PURSUE THIS CHART ANY FURTHER. IF HE FINDS AN UNFAVORABLE TREND, HE MOVES TO THE RIGHT-HAND SIDE OF THE FIGURE TO CHECK PROGRESS WITHIN EACH SYSTEM WHCIH CAN BE IDENTIFIED WITHIN THE ENTIRE NETWORK. IN THIS WAY HE CAN IDENTIFY WHICH MAJOR SYSTEMS ARE CAUSING THE DELAYS OR PROBLEMS. HAVING IDENTIFIED THE SYSTEM HE WISHES TO PURSUE, HE MOVES TO THE SUMMARY BAR GRAPH FOR THAT SYSTEM. HE THEN IDENTIFIES WHAT STAGE OF EVOLUTION IT IS IN, AND POSSIBLY WHAT IS CAUSING THE DELAY. THE MANAGER THEN MOVES DIRECTLY TO THE POINT OF DIFFICULTY WITHOUT UNDUE DELAY AND IS ABLE TO IMPLEMENT CORRECTIVE PROCEDURES RAPIDLY AND EFFICIENTLY. THE CONTROL GROUP WORKING IN COORDINATION WITH MANAGEMENT AND PROJECT PERSONNEL, IS ABLE TO INCLUDE IN THE REVISED NETWORK THE NECESSARY CORRECTIONS TO THE PROJECT. THIS GROUP THEN DEVELOPS NEW BAR GRAPHS AND INSTRUCTION FOR IMPLEMENTING MANAGEMENT DECISIONS. NEW SCHEDULES ARE THEN SUBMITTED TO THE FIELD AND TO MANAGEMENT FOR REVIEW.

NETWORK DESIGN, ORGANIZATION, AND REPORTING FORMS ARE NECESSARY TECHNIQUES FOR THE SUCCESSFUL USE OF PERT. HOWEVER, THESE ARE ALL TECHNICAL ASPECTS. FOR PERT TO BE USED EFFECTIVELY WITH A COMPANY, ADEQUATE INSTRUCTION IN THE CONCEPTS AND CORRECT USES OF THIS TECHNIQUE SHOULD BE GIVEN TO ALL PERSONNEL INVOLVED, FROM MANAGEMENT THROUGH FIELD PERSONNEL.

SOURCE...REFERENCE10

PERT Cycle Illustration


Inputs
From Contractor
Biweekly
Monthly
Adjustments
Flow
Diagram
Outlook
Evaluation
Critical
Thread
Overall
MGMT
Event
File
Detailed
Info.
Technical
Direction
Staff
Outputs
Elapsed Time
Estimates
Computer
Effect of
Proposed Change
Analysis of Proposed Change
Proposed Change

PERT System in Operation

FIGURE A0

PERT OUTLINE

Figure A1

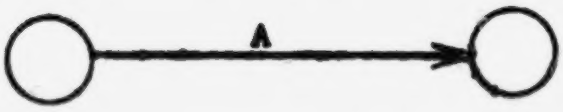
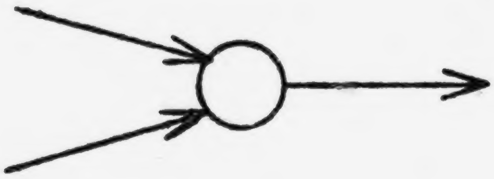
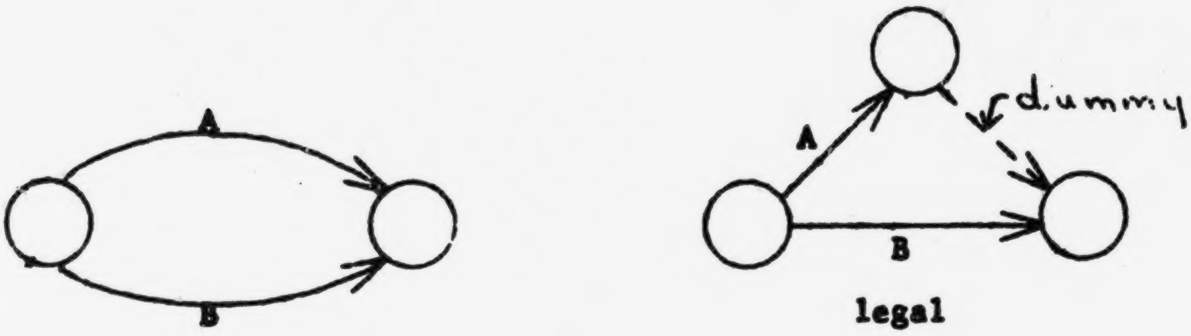


Figure A2



Figures A3



illegal

legal

Figure A4

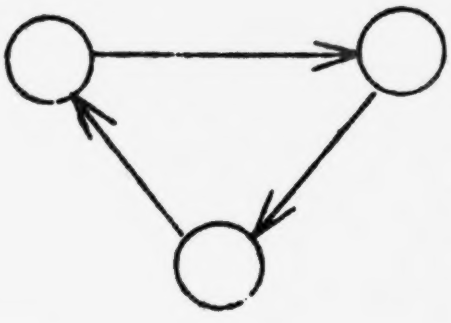
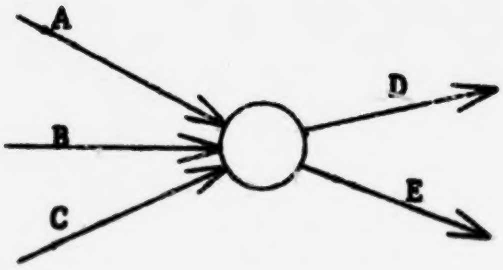
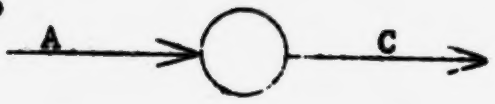


Figure A5



Figures A6



and

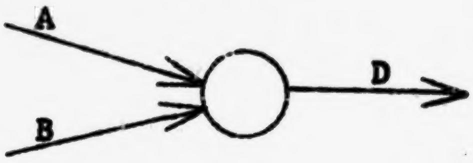


Figure A7

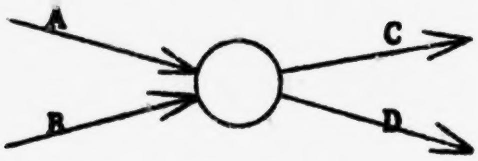
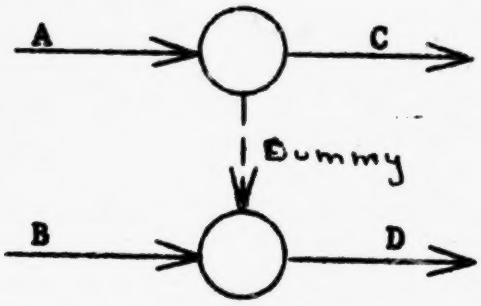


Figure A8



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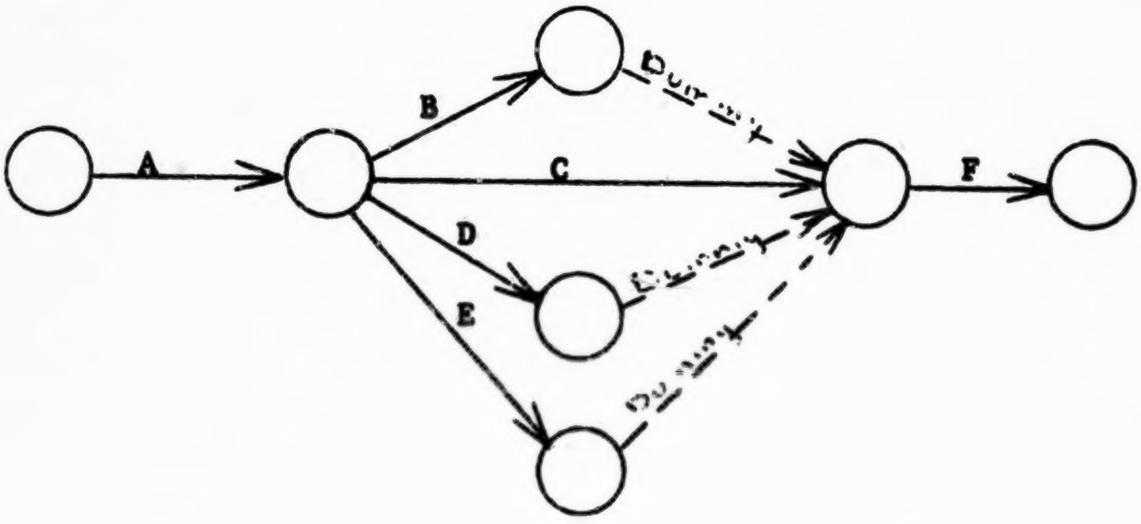
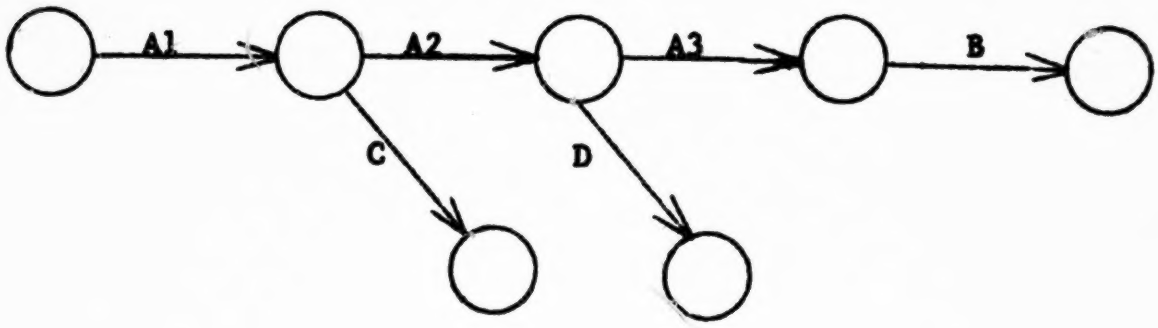

A
B
C
D
E
F
Dummy
Dummy
Dummy

Figure A10



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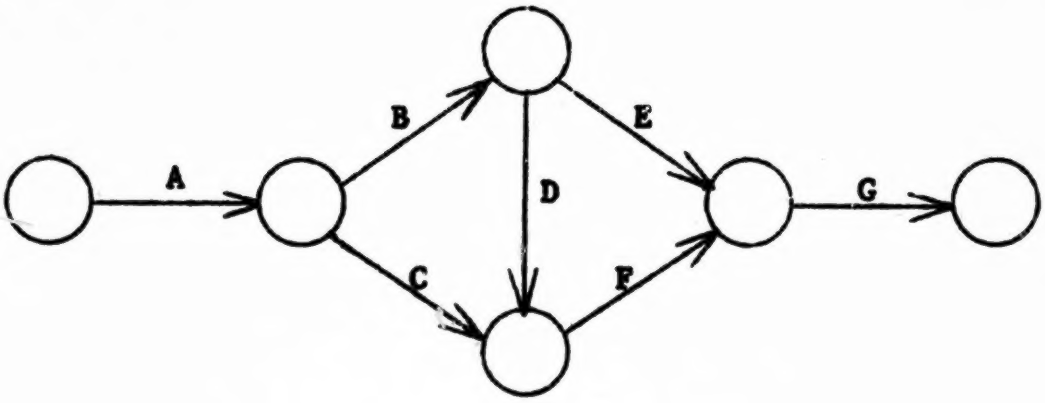


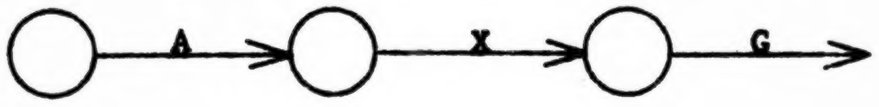
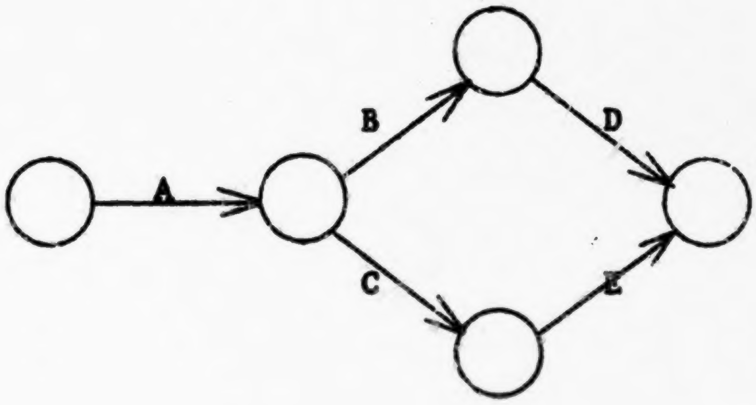


Figure A12



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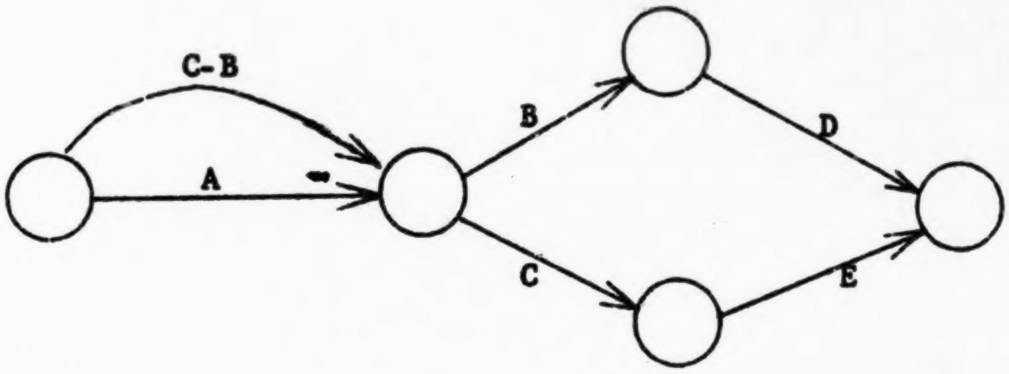


Figure A14

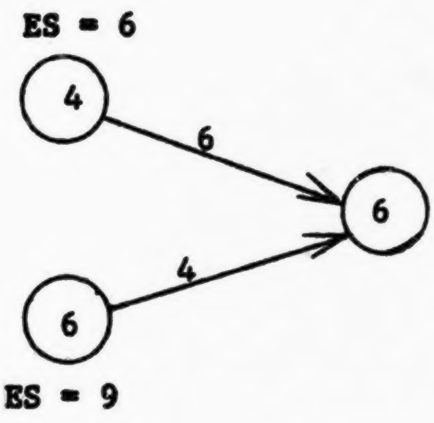

ES = 6
4
6
6
4
6
ES = 9

Figure A15

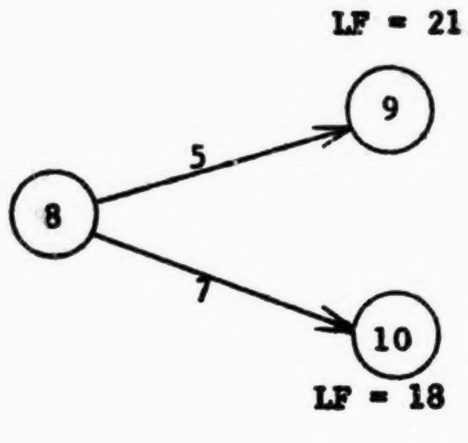

LF = 21
9
5
8
7
10
LF = 18

Figure A16

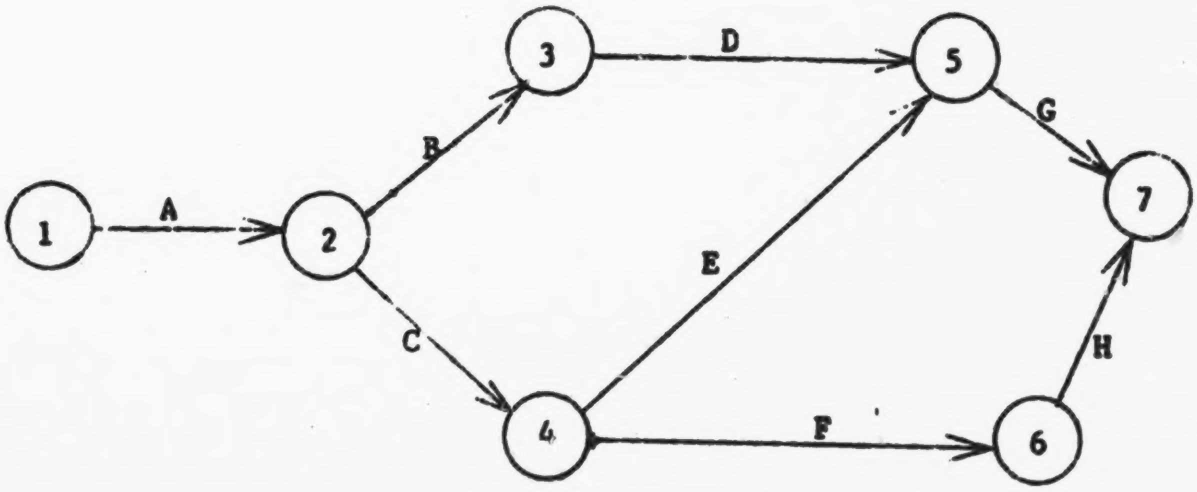
HEAD

TAIL

ES	i \ j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0																					
	1																				
	2																				
	3																				
	4																				
	5																				
	6																				
	7																				
	8																				
	9																				
	10																				
	11																				
	12																				
	13																				
	14																				
	15																				
	16																				
	17																				
	18																				
	19																				
	20																				

LF																				

Figure A17


1
A
2
B
C
3
D
4
E
F
5
G
6
H
7

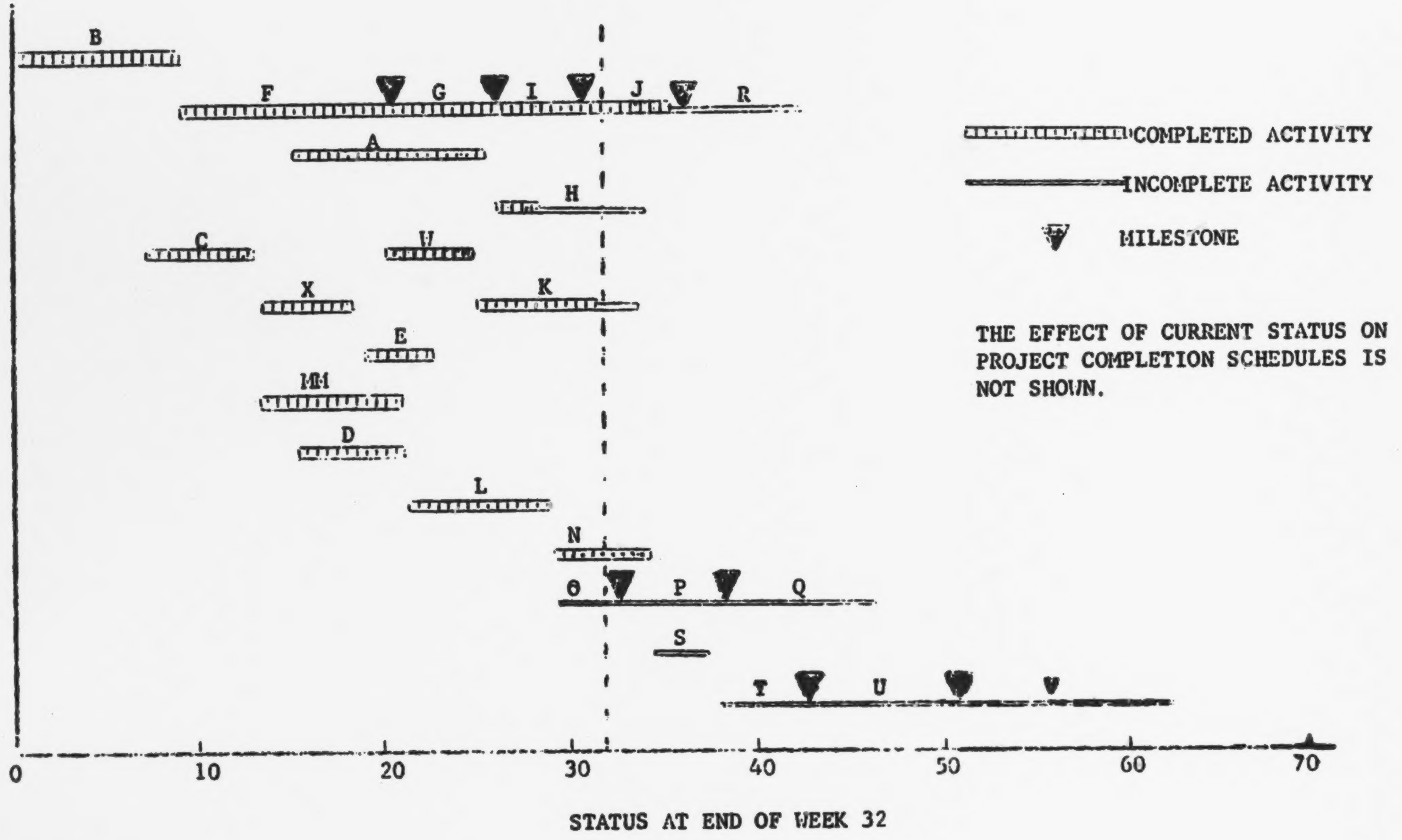
Activity	i	j	Duration
A	1	2	3
B	2	3	4
C	2	4	5
D	3	5	2
E	4	5	3
F	4	6	4
G	5	7	1
H	6	7	3

ES	i / j	1	2	3	4	5	6	7
0	1		3					
3	2			4	5			
7	3					2		
8	4					3	4	
11	5							1
12	6							3
15	7							

LF	0	3	12	8	14	12	15

TRADITIONAL BAR CHART

OF NETWORK



THE EFFECT OF CURRENT STATUS ON PROJECT COMPLETION SCHEDULES IS NOT SHOWN.

FIGURE A18

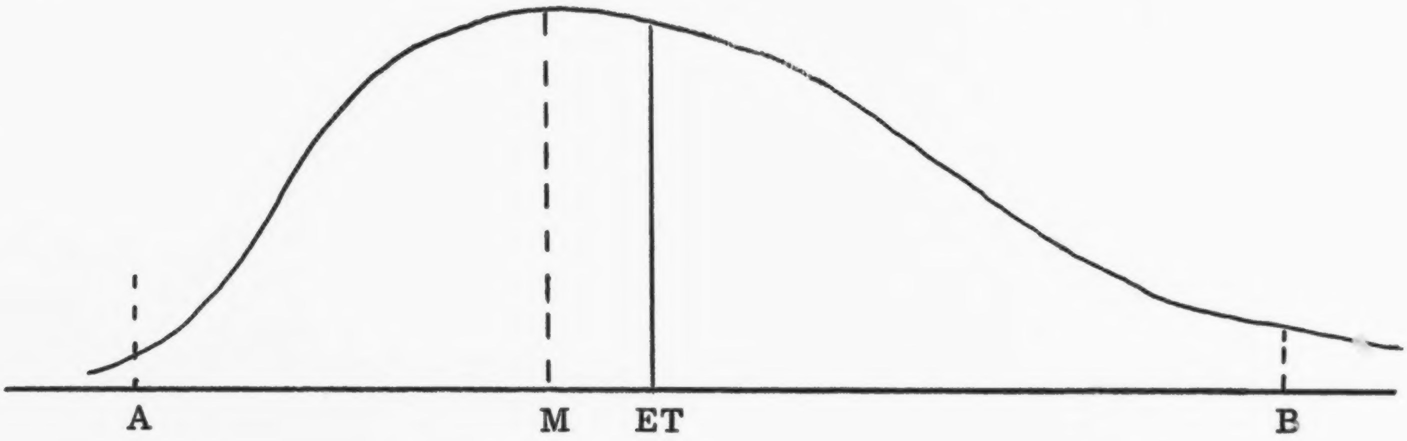
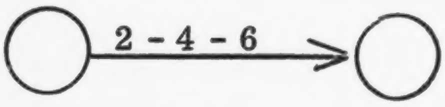


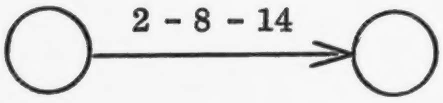
Figure B-0



A=2, M=4, B=6

$$ET = \frac{A + 4M + B}{6} = \frac{2 + 16 + 6}{6} = 4$$

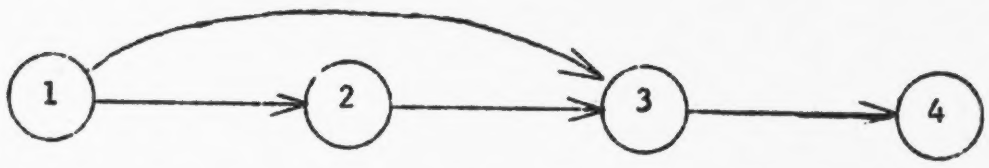
Figure B-1



A=2, M=8, B=14

$$VARET = \left(\frac{B - A}{6}\right)^2 \qquad \left(\frac{14-2}{6}\right)^2 = 4$$

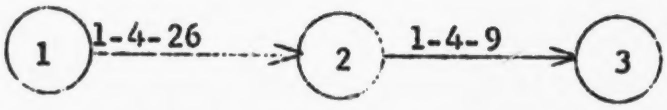
Figure B-2



I	J	A	M	B	ET	TE	VARET	VARTE
1	3	2	8	14	2	2	4	
1	2	2	4	6	4	4	.44	
2	3	1	2	3	2	6	.11	.55

VARTE = .44 + .11 = .55 since activities 1-2 and 2-3 determine the ES of 3-4.

Figure B-3



$$K = \frac{TS-TE}{\sqrt{VARTE}}$$

Where $\sqrt{VARTE}$ = Standard Deviation of TE

I	J	A	M	B	ET	TE	VARET	VARTE	TS
1	2	1	4	26	7.2	7.2	17.35	17.35	
2	3	1	4	9	4.3	11.5	1.77	19.12	8

$$\sqrt{VARTE} = \sqrt{19.12} = 4.4$$

$$K = \frac{8 - 11.5}{4.4} = -.8$$

So by referring to Figure B-5, the probability of meeting A TS date of 8 is .212.

Figure B-4

PK PROBABILITY TABLE

K	0	1	2	3	4	5	6	7	8	9
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5483	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7703	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9278	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9430	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9648	.9556	.9664	.9671	.9678	.9686	.9693	.9700	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9762	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9874	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3. 0	.9987	.9990	.9993	.9995	.9997	.9998	.9998	.9999	.9999	1.0000

FIGURE B5. POSITIVE K VALUES.

PK PROBABILITY TABLE

K	0	1	2	3	4	5	6	7	8	9
-3.0	.0013	.0010	.0007	.0005	.0003	.0002	.0002	.0001	.0001	.0000
-2.9	.0019	.0018	.0017	.0017	.0016	.0016	.0015	.0015	.0014	.0014
-2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
-2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
-2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
-2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
-2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
-2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
-2.2	.0139	.0136	.0132	.0129	.0126	.0122	.0119	.0116	.0113	.0110
-2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
-2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
-1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0238	.0233
-1.8	.0359	.0352	.0344	.0336	.0329	.0322	.0314	.0307	.0300	.0294
-1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
-1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
-1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0570	.0559
-1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0722	.0708	.0694	.0681
-1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
-1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
-1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
-1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
- .9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
- .8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
- .7	.2420	.2389	.2358	.2327	.2297	.2266	.2236	.2206	.2177	.2148
- .6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
- .5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
- .4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
- .3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
- .2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
- .1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
- .0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641

FIGURE B5. NEGATIVE K VALUES.

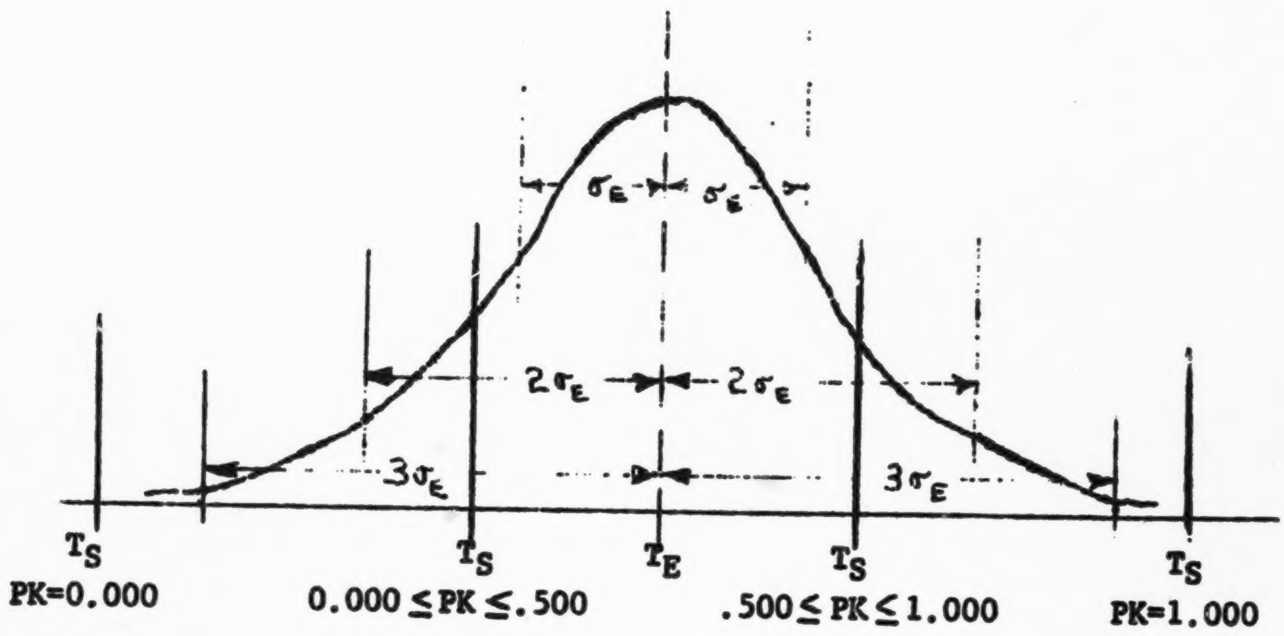
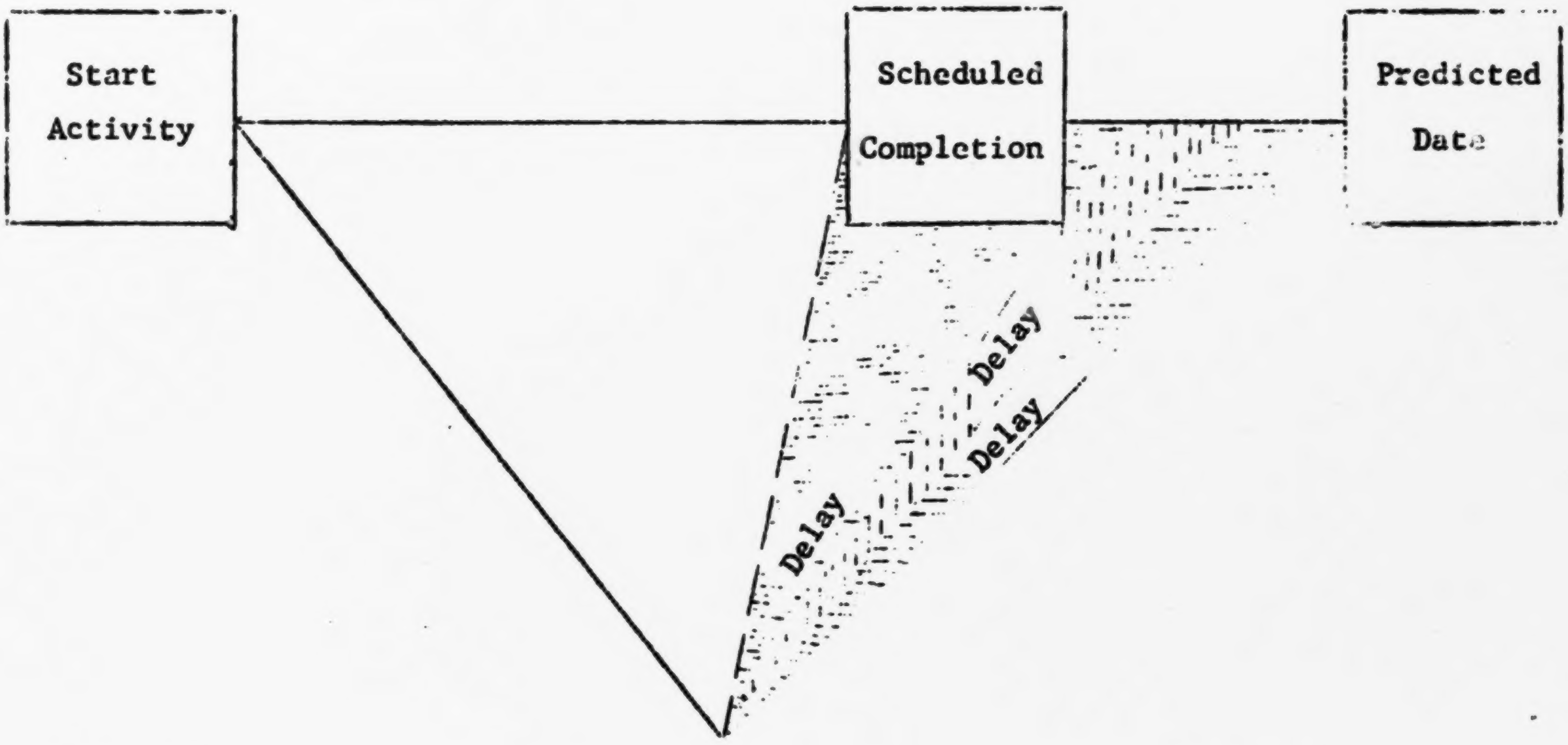

σ_E
σ_E
$2\sigma_E$
$2\sigma_E$
$3\sigma_E$
$3\sigma_E$
T_S
PK=0.000
T_S
0.000 ≤ PK ≤ .500
T_E
T_S
.500 ≤ PK ≤ 1.000
T_S
PK=1.000

Figure B-6

PERT
PREDICTED DATE-SCHEDULED DATE-RELATIONSHIP
BASIC THEORY


Start Activity
Scheduled Completion
Predicted Date
Delay
Delay
Delay

EXPLANATION

A scheduled date is a target date.

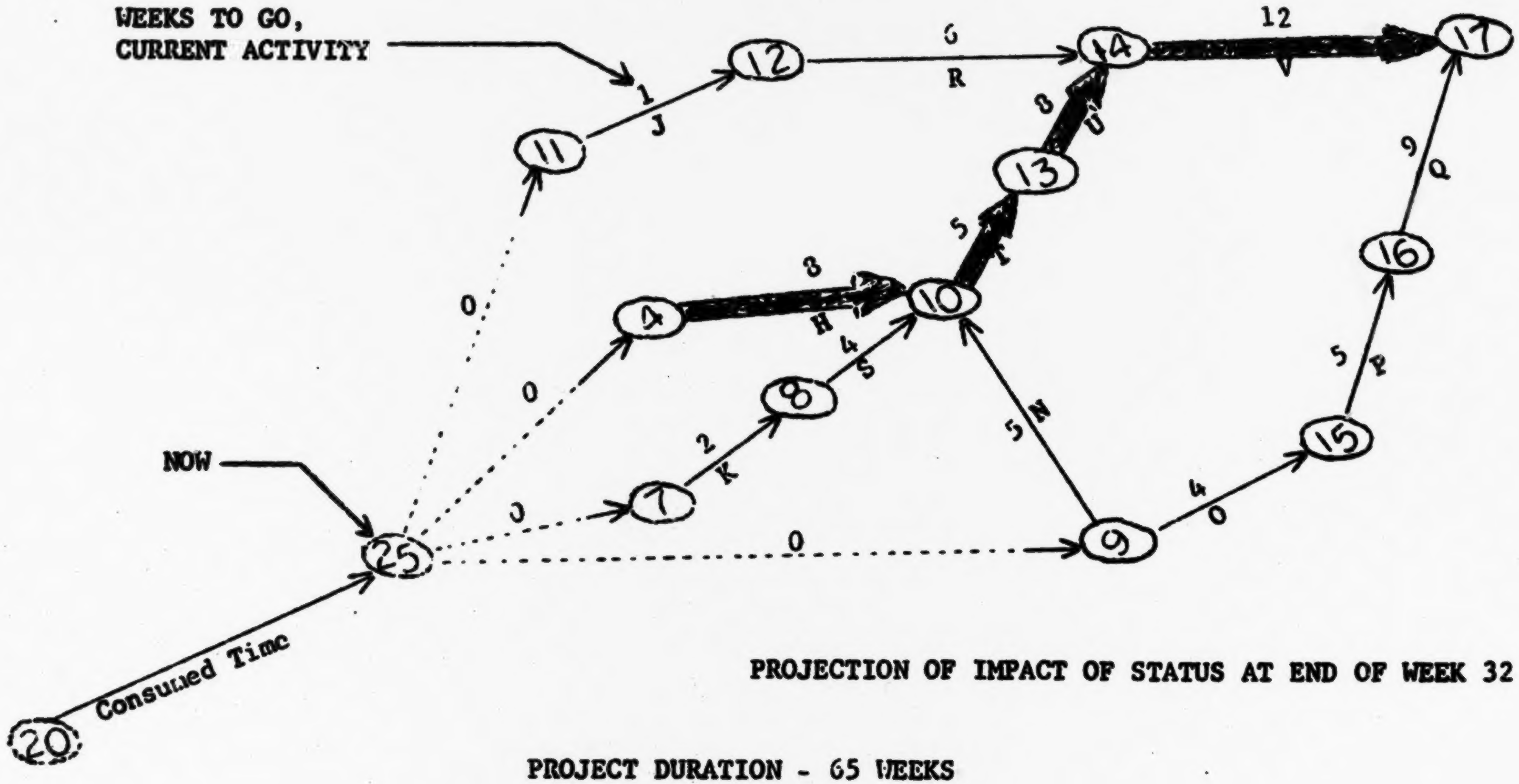
A predicted date is a capability date.

A scheduled date plus delays, or minus advancements, equals a predicted date.

PERT Techniques assist in pinpointing such delays and advancements and in directing the shifting of men and facilities to eliminate or minimize delays in order to meet scheduled (Target) dates.

Figure B-7

S T A T U S   R E P O R T I N G


WEEKS TO GO,
CURRENT ACTIVITY
NOW
Consumed Time
20
25
0
11
1
J
12
6
R
14
12
V
17
0
4
8
H
10
5
T
13
8
U
0
7
2
K
8
4
S
0
9
5
N
4
O
15
5
P
16
9
Q

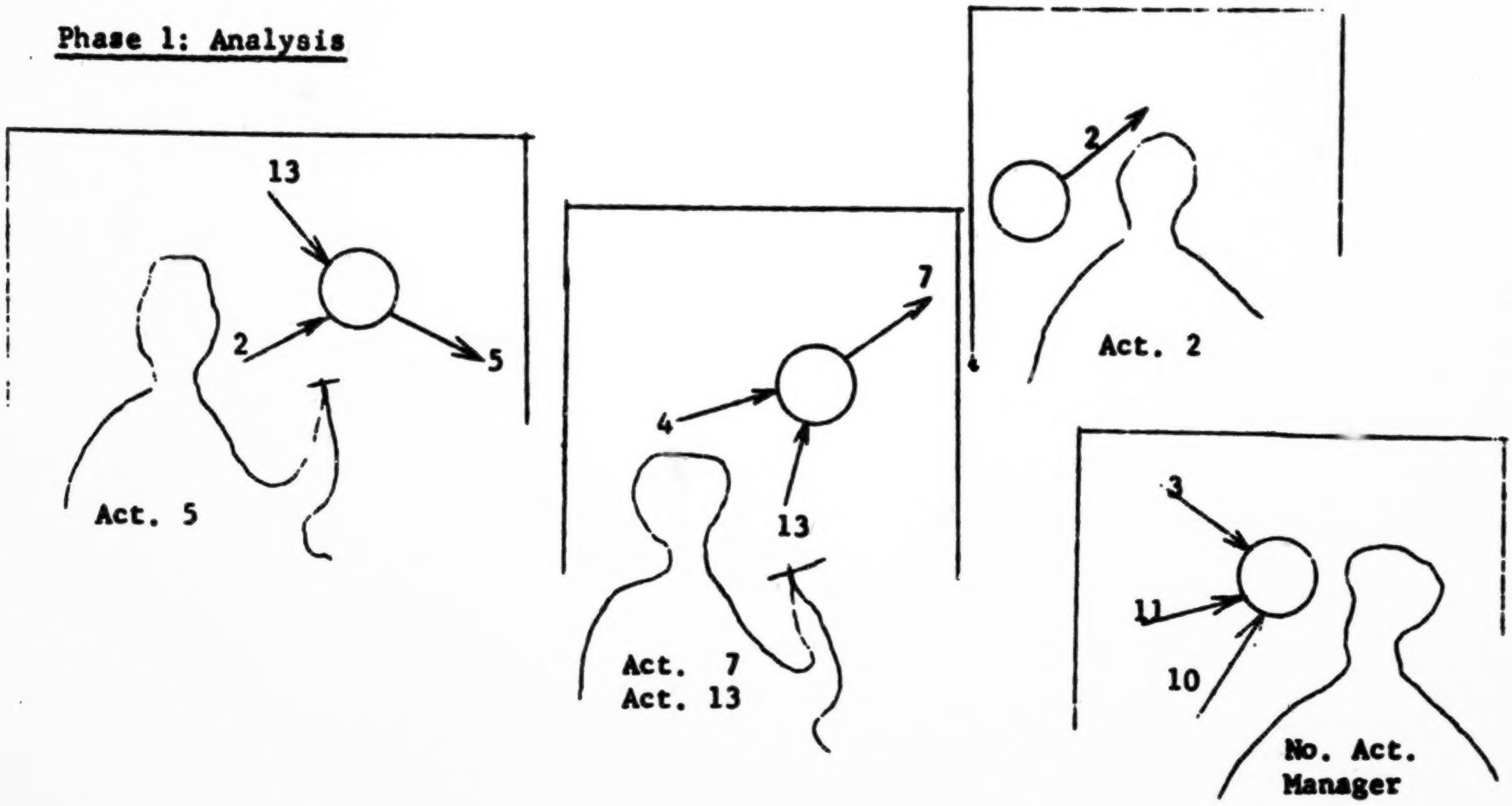
PROJECTION OF IMPACT OF STATUS AT END OF WEEK 32

PROJECT DURATION - 65 WEEKS

(2 Weeks Behind Schedule)

FIGURE B-8

Phase 1: Analysis


13
2
5
Act. 5
7
4
13
Act. 7
Act. 13
2
Act. 2
3
11
10
No. Act.
Manager

Phase 2: Synthesis

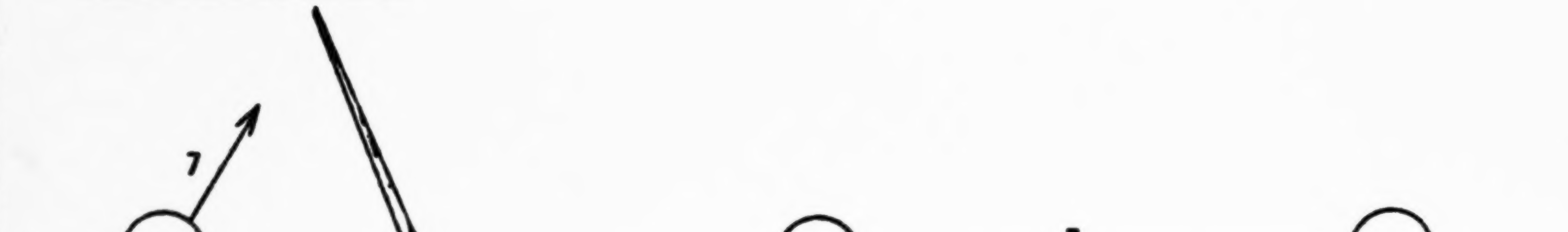

7
4
13
13
2
5
3
11
10
7
4
13
12
11
2
5
3
6
8
10
1
9

FIGURE B-9

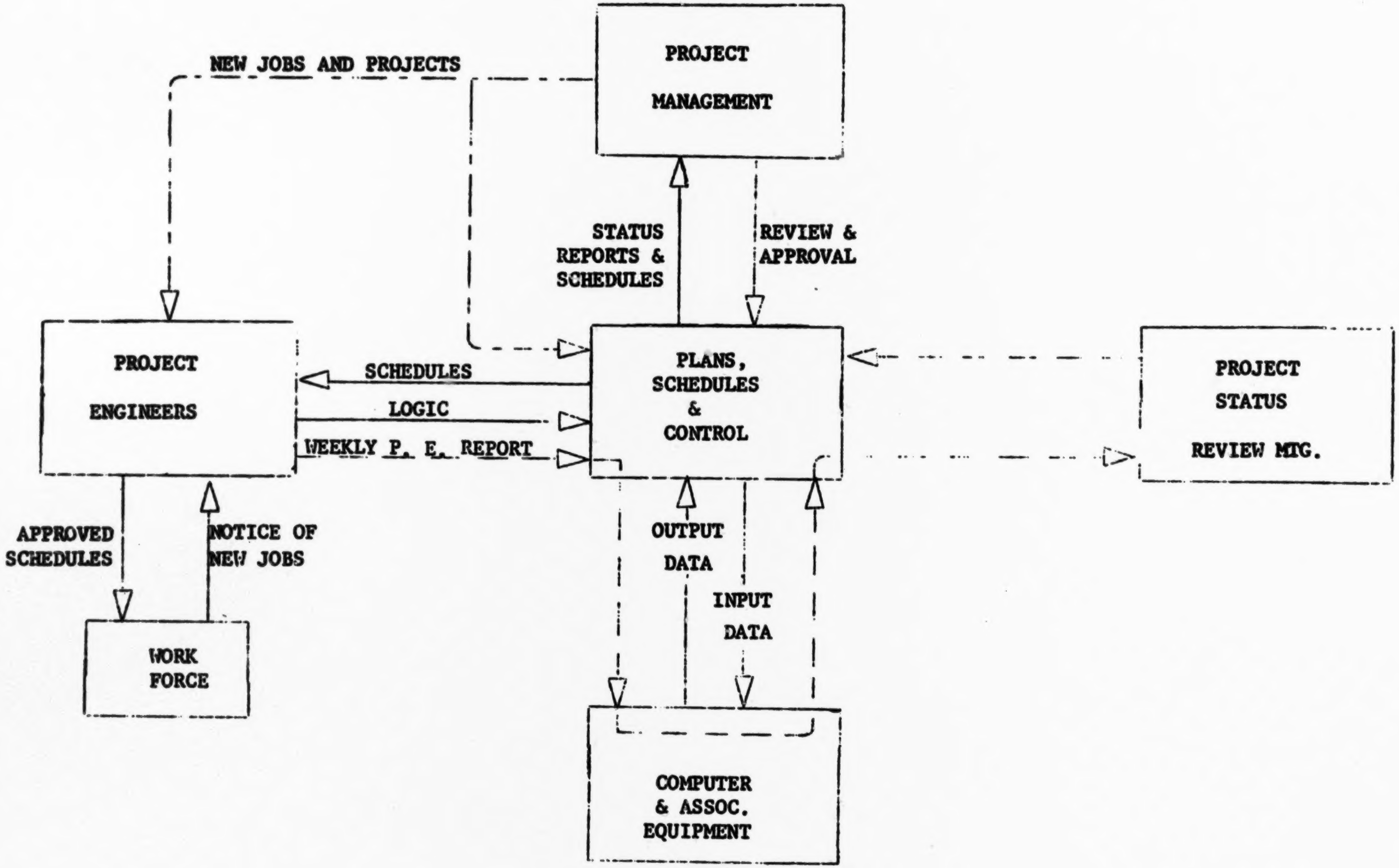
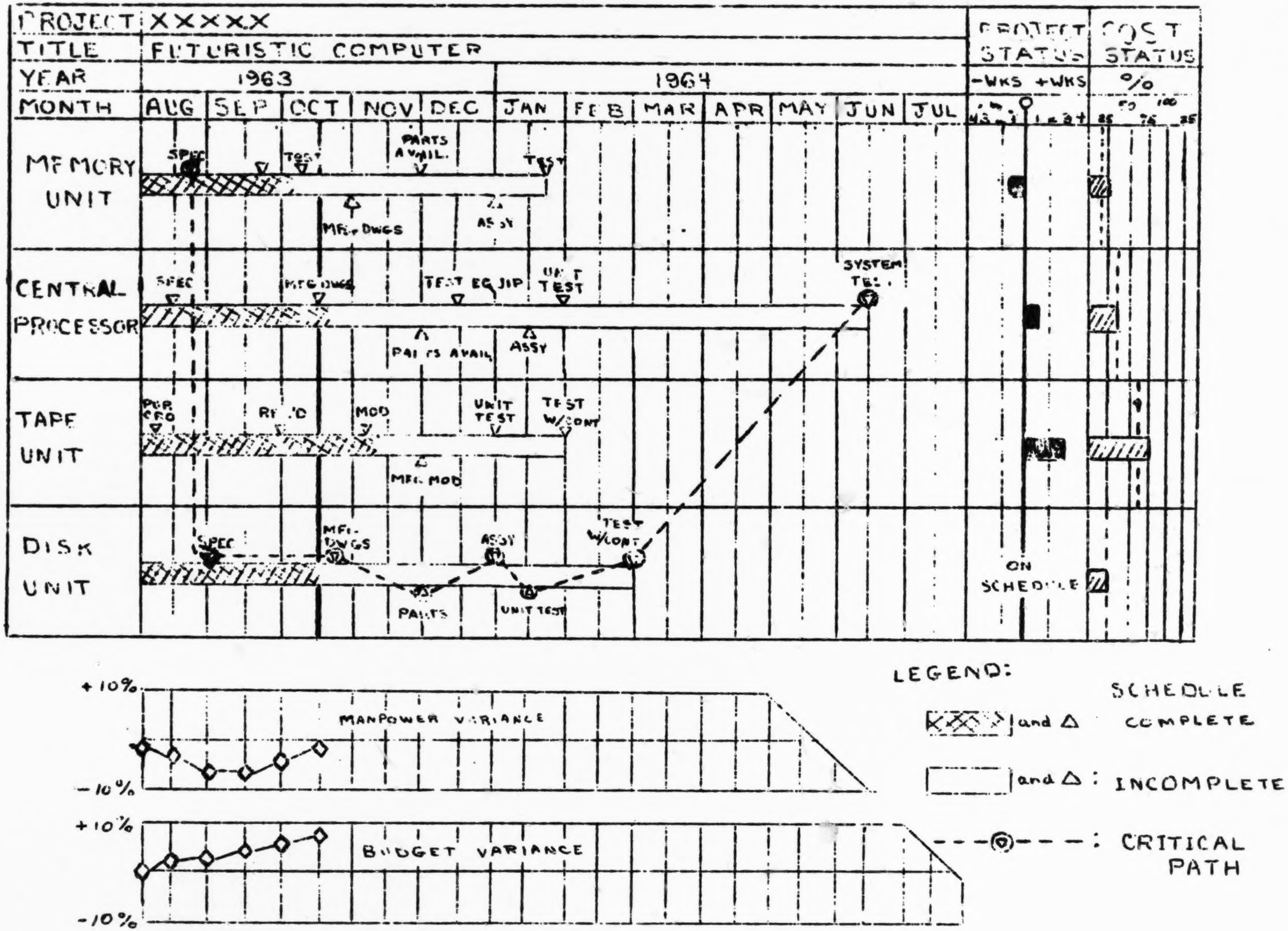

NEW JOBS AND PROJECTS
PROJECT MANAGEMENT
STATUS REPORTS & SCHEDULES
REVIEW & APPROVAL
PROJECT ENGINEERS
SCHEDULES
LOGIC
WEEKLY P. E. REPORT
PLANS, SCHEDULES & CONTROL
PROJECT STATUS REVIEW MTG.
APPROVED SCHEDULES
NOTICE OF NEW JOBS
WORK FORCE
OUTPUT DATA
INPUT DATA
COMPUTER & ASSOC. EQUIPMENT

FIGURE D-1



MANAGEMENT SUMMARY REPORT

FIGURE D.2

PERT BAR CHART

Of Network

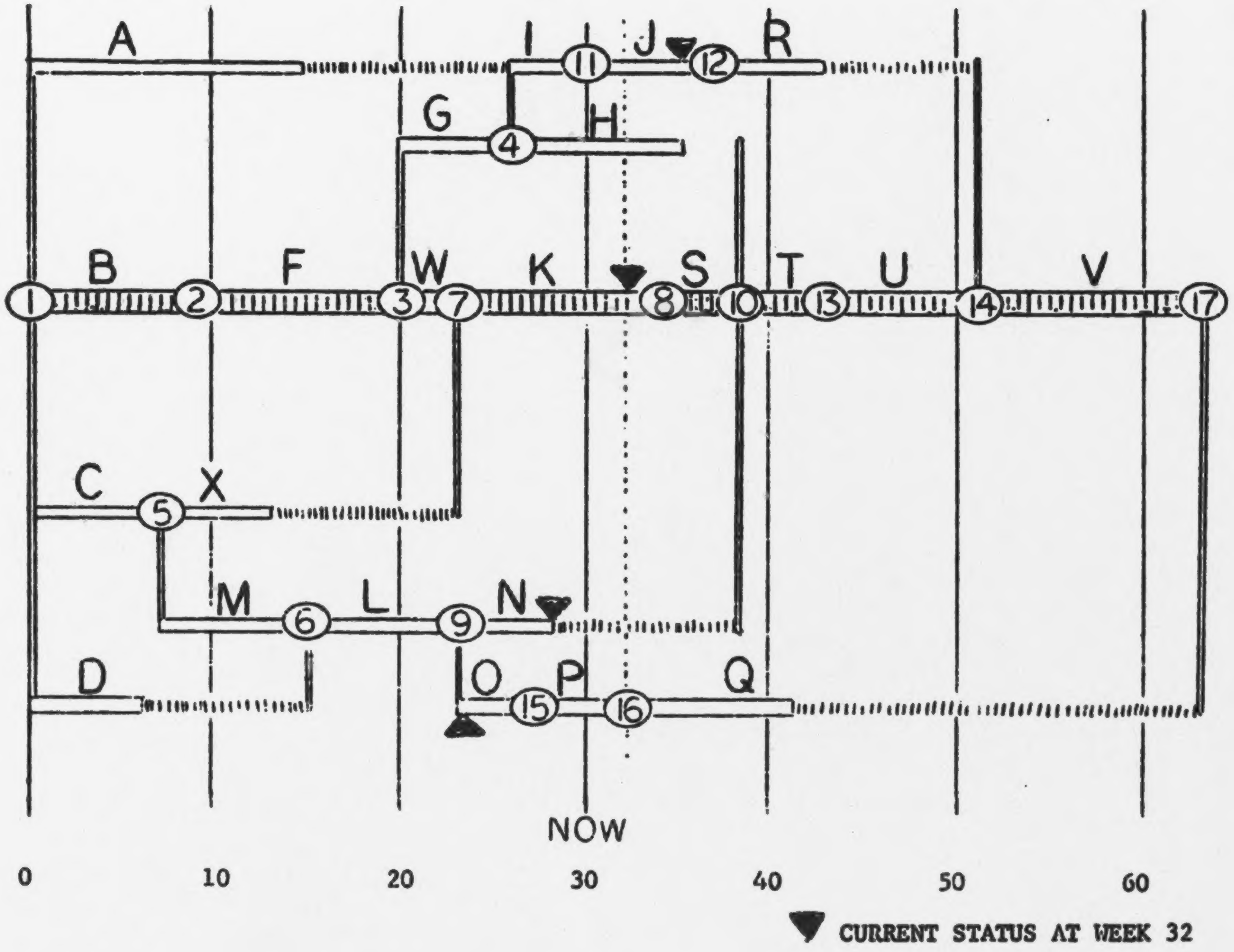

A
I
J
R
G
H
B
F
W
K
S
T
U
V
C
X
M
L
N
D
O
P
Q
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
NOW
0
10
20
30
40
50
60
▼ CURRENT STATUS AT WEEK 32

FIGURE D-3

PROGRESS EVALUATION REPORT

I	J	Activity Description	Scheduled[1] Completion	Estimated or Actual Completion	PERT Total Float	Total Float remaining[2] + or -	Comments

1. Including free float.

2. Use minus sign if total float exceeded.

FIGURE D-5

NARRATIVE REPORT FORM

1. GENERAL CONDITIONS

1.1 IN GOOD SHAPE

ALL ASPECTS OF THE PROGRAM ARE PROGRESSING SATISFACTORILY AS EVIDENCED BY PERFORMANCE FACTS. THERE ARE NO IMMEDIATE PROBLEMS WHICH MAY ENDANGER PROGRAM ACCOMPLISHMENT. MILESTONE SLIPPAGES, IF ANY, CAN BE RESCHEDULED WITHOUT REQUIRING A SIGNIFICANT AMOUNT OF ADDITIONAL EFFORT AND WITHOUT REQUIRING RESCHEDULING OF OTHER MILESTONES.

1.2 MINOR WEAKNESS

THE PROGRAM IS GENERALLY PROGRESSING SATISFACTORILY, BUT SOME EVENT, ACTION, OR DELAY HAS OCCURRED OR IS ANTICIPATED WHICH WILL REQUIRE ADDITIONAL EFFORT AND EMPHASIS ON THE PART OF THE RESPONSIBLE DIVISION. NO MAJOR SETBACK IS ANTICIPATED ON THE PROGRAM AND NO ACTION IS REQUIRED ABOVE THE DIVISION LEVEL.

1.3 MAJOR WEAKNESS

SOME EVENT, ACTION, OR DELAY HAS OR WILL OCCUR WHICH WILL IMPAIR PROGRESS AGAINST MAJOR OBJECTIVES IN ONE OR MORE DIVISIONS, REQUIRING TIMELY ACTION BY TOP MANAGEMENT OR BY THE PROGRAM MANAGER. REQUIRED ACTION MAY BE A POLICY DECISION, AN APPEAL TO A HIGHER AUTHORITY FOR ASSISTANCE, OR DECISION, ETC.

1.4 CRITICAL

SOME EVENT, ACTION OR DELAY HAS OR WILL OCCUR WHICH SERIOUSLY IMPEDES A SUCCESSFUL ACCOMPLISHMENT OF ONE OR MORE MAJOR PROGRAM OBJECTIVES. SUCH A SETBACK TO THE PROGRAM REQUIRES REORIENTATION OR REPROGRAMMING OF THE EFFORT, WITH THE ADVICE AND CONSENT OF TOP MANAGEMENT.

2. SPECIFY WEAKNESSES

2.1 PROBLEM
2.2 RESPONSIBLE INDIVIDUAL
2.3 CORRECTIVE ACTION RECOMMENDED OR BEING TAKEN
2.4 ANTICIPATED DATE PROBLEM WILL BE RESOLVED.

3. SPECIFY ANTICIPATED SIGNIFICANT ACHIEVEMENTS.

FIGURE D4

GLOSSARY OF TERMS

ACTIVITY

AN ELEMENT OF A PROJECT WHICH IS REPRESENTED ON A NETWORK BY AN ARROW. AN ACTIVITY CANNOT BE STARTED UNTIL THE EVENT PRECEDING IT HAS OCCURRED. AN ACTIVITY MAY REPRESENT

- A PROCESS
- A TASK
- A PROCUREMENT CYCLE
- WAITING TIME

IN ADDITION, AN ACTIVITY MAY SIMPLY REPRESENT A CONNECTION OR INTERDEPENDENCY BETWEEN TWO EVENTS ON THE NETWORK.

ACTIVITY SLACK

THE DIFFERENCE IN TIME, COMPARING THE EARLIEST COMPLETION DATE ES WITH THE LATEST COMPLETION DATE LF FOR A GIVEN ACTIVITY. THE ACTIVITY SLACK INDICATES THE RANGE OF TIME WITHIN WHICH AN ACTIVITY CAN BE SCHEDULED FOR COMPLETION. WHEN THE ES FOR AN ACTIVITY IS LATER THAN THE LF, THEN THE ACTIVITY IS SAID TO HAVE NEGATIVE SLACK AND EITHER THE CURRENT OR SUBSEQUENT ACTIVITIES MUST BE REPLANNED OR THE PROJECT SCHEDULE WILL SLIP. WHEN THE LF FOR AN ACTIVITY IS LATER THAN THE ES, THEN THE ACTIVITY IS SAID TO HAVE POSITIVE SLACK AND ADDITIONAL TIME IS AVAILABLE FOR PERFORMING THE ACTIVITY WITHOUT CAUSING THE PROJECT SCHEDULE TO SLIP.

CONSTRAINT

THE RELATIONSHIP OF AN EVENT TO A SUCCEEDING ACTIVITY WHEREIN AN ACTIVITY MAY NOT START UNTIL THE EVENT PRECEDING IT HAS OCCURRED. THE TERM CONSTRAINT IS ALSO USED TO INDICATE THE RELATIONSHIP OF AN ACTIVITY TO A SUCCEEDING EVENT WHEREIN AN EVENT CANNOT OCCUR UNTIL ALL ACTIVITIES PRECEDING IT HAVE BEEN COMPLETED.

COST ACTIVITY

AN ACTIVITY WHICH EMPLOYS RESOURCES, THE COSTS OF WHICH ARE A DIRECT CHARGE TO THE PROJECT.

CRITICAL PATH

THAT PARTICULAR SEQUENCE OF ACTIVITIES THAT HAS THE GREATEST NEGATIVE OR LEAST POSITIVE ACTIVITY SLACK.

EARLIEST COMPLETION DATE TE

THE SE VALUE FOR A GIVEN ACTIVITY IS EQUAL TO THE SUM OF THE SCHEDULED ELAPSED TIMES TS FOR THE ACTIVITIES ON THE LONGEST PATH FROM THE BEGINNING OF THE PROJECT UP TO AND INCLUDING THE GIVEN ACTIVITY. THEREFORE, TE REPRESENTS THE EARLIEST DATE ON WHICH AN ACTIVITY CAN BE COMPLETED.

EARLIEST EXPECTED DATE ES

THE EARLIEST DATE ON WHICH AN EVENT CAN BE EXPECTED TO OCCUR.

THE TE VALUE FOR A GIVEN EVENT IS EQUAL TO THE SUM OF THE STATISTICALLY-CALCULATED EXPECTED ELAPSED TIMES ET FOR THE ACTIVITIES ON THE LONGEST PATH FROM THE BEGINNING OF THE PROJECT TO THE GIVEN EVENT.

ESTIMATE-TO-COMPLETE

THE ESTIMATED MANHOURS, COSTS AND TIME REQUIRED TO COMPLETE A WORK PACKAGE OR SUMMARY WORK PACKAGE.

EVENT

A SPECIFIC DEFINABLE ACCOMPLISHMENT IN A PROJECT PLAN, RECOGNIZABLE AT A PARTICULAR INSTANT IN TIME. EVENTS DO NOT CONSUME TIME OR RESOURCES, AND ARE NORMALLY REPRESENTED IN THE NETWORK BY CIRCLES OR RECTANGLES.

EVENT SLACK

THE DIFFERENCE BETWEEN THE EARLIEST EXPECTED DATE ES AND THE LATEST ALLOWABLE DATE LF FOR A GIVEN EVENT. WHEN THE TE FOR AN EVENT IS LATER THAN THE LF, THE EVENT IS SAID TO HAVE NEGATIVE SLACK. WHEN THE LF IS LATER THAN THE ES, THE EVENT IS SAID TO HAVE POSITIVE SLACK.

EXPECTED ELAPSED TIME ET

A STATISTICALLY-WEIGHTED AVERAGE TIME FOR AN ACTIVITY, INCORPORATING THE OPTIMISTIC A , MOST LIKELY M AND PESSIMISTIC B TIME ESTIMATES.

LATEST ALLOWABLE DATE LF

THE LATEST DATE ON WHICH AN EVENT CAN OCCUR WITHOUT CREATING AN EXPECTED DELAY IN THE COMPLETION OF THE PROJECT. THE LF VALUE FOR A GIVEN EVENT IS CALCULATED BY SUBTRACTING THE SUM OF THE EXPECTED ELAPSED TIMES ET FOR THE ACTIVITIES ON THE LONGEST PATH FROM THE GIVEN EVENT TO THE END EVENT OF THE PROJECT FROM THE LATEST DATE ALLOWABLE FOR COMPLETING THE PROJECT. LF FOR THE END EVENT IN A PROJECT IS EQUAL TO THE DIRECTED DATE TD OF THE PROJECT. IF A DIRECTED DATE IS NOT SPECIFIED, TL TE FOR THE END EVENT.

MOST LIKELY TIME ESTIMATE M

THIS IS THE MOST REALISTIC ESTIMATE OF THE TIME AN ACTIVITY MIGHT CONSUME. THIS TIME WOULD BE EXPECTED TO OCCUR MOST OFTEN IF THE ACTIVITY COULD BE REPEATED NUMEROUS TIMES UNDER SIMILAR CIRCUMSTANCES.

NETWORK

A FLOW PLAN CONSISTING OF ALL THE ACTIVITIES AND EVENTS THAT MUST BE ACCOMPLISHED TO REACH THE PROJECT OBJECTIVES, SHOWING THE SEQUENCES IN WHICH THEY ARE PLANNED TO BE ACCOMPLISHED AND THEIR INTERDEPENDENCIES, AND INTERRELATIONSHIPS.

OPTIMISTIC TIME ESTIMATE A

THE TIME IN WHICH THE ACTIVITY CAN BE COMPLETED IF EVERYTHING GOES EXCEPTIONALLY WELL. IT IS ESTIMATED THAT AN ACTIVITY WOULD HAVE

NO MORE THAN ONE CHANCE IN A HUNDRED OF BEING COMPLETED WITHIN THIS TIME.

PESSIMISTIC TIME B

THE TIME REQUIRED FOR AN ACTIVITY UNDER ADVERSE CONDITIONS, BARRING ACTS OF GOD. IT IS ESTIMATED THAT AN ACTIVITY WOULD HAVE NO MORE THAN ONE CHANCE IN A HUNDRED OF EXCEEDING THIS AMOUNT OF TIME.

SCHEDULED COMPLETION DATE FOR AN ACTIVITY TS

A DATE ASSIGNED FOR COMPLETION OF AN ACTIVITY FOR PURPOSES OF PLANNING AND CONTROL WITHIN AN ORGANIZATION. WHERE NO SPECIFIC DATE IS ASSIGNED, TE TS.

STANDARD DEVIATION

MATHEMATICALLY, THE SQUARE ROOT OF THE ARITHMETIC MEAN OF THE SQUARES OF THE DEVIATIONS OF THE VARIOUS ITEMS FROM THE ARITHMETIC MEAN OF THE WHOLE. COMMON PERT PRACTICE IN REFERENCE TO THE THREE TIME ESTIMATES A, M, B USES A STANDARD DEVIATION EQUAL TO ONE-SIXTH OF THE RANGE OF THE DISTRIBUTION CURVE.

VARIANCE

A STATISTICAL TERM EQUAL TO THE STANDARD DEVIATION SQUARED.

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